



**40th Annual Armament Systems: Guns - Ammunition - Rockets - Missiles  
Conference & Exhibition**  
*"Translating Lessons Learned into Systems Requirements"*

**25 -28 April 2005**

**Agenda**

Tuesday, 26 April 2005

**General Session:**

- Weapons Systems and Explosives Safety in a Joint Warfighting Environment, Mr. David C. Schulte, Executive Director, Naval Ordnance Safety & Security Activity
- The Future of Small Missiles, Dr. James C. Bradas, Associate Director for Missile Technology, AMERDEC

**Session: Modeling & Simulation**

- Accuracy Modeling of the 120mm M256 Gun as a Function Of Bore Centerline Profile, Mr. David Smith for Dr. Ronald Gast, Benet Laboratories
- Opening New "DOORS" to Managing JSF Gun System Requirements, Ms. Renee I. Bellack, General Dynamics Armament and Technical Products
- Optimized Trajectory Shaping Guidance for an Air-to-Ground Missile Launched from a Gunship, Mr. Shane Sorenson, Naval Surface Warfare Center
- Estimating Ballistic Limits of Skin and Clothing for Projectiles, Mr. Henry E. Hudgins, US Army ARDEC
- A Review of The Insensitive Munitions Design Technology Workshop, Mr. M. Pascal Marchandin, NATO-MSIAC

**Luncheon:**

- Super Weapons – An Analysis, LTC Simon R. West, British Army, United Kingdom Defence Academy

**Session: Medium Caliber System**

- Oerlikon Ammunition for New Defense Environment, Mr. Allan N. Buckley, BTECH Oerlikon Contraves Pyrotec AG
- Multi Mission Vehicle Armament & Air Burst Munition for Expeditionary Warfare Force Protection, Mr. Andrew Bradick, Lockheed Martin
- 25mm Gun Systems for the F-35 Joint Strike Fighter (JSF), Mr. Douglass C. Parker, General Dynamics Armament and Technical Products
- Optimized Gun Barrel Targeting Investigation, Mr. Jeff A. Siewart, Arrow Tech Association
- Mk 110 Mod 0 / 57mm Naval Gun & Ammunition Certification Process, LT Timothy J. Hackett, USCG, US Coast Guard Deepwater Sponsors' Representative
- GAU-19/A Barrel Life Study, Mr. James J. St. Germain, General Dynamics Armament & Technology Products
- RNLA IFV Firepower: 30 mm versus 35 mm - 35 mm KETF Firing doctrine, Mr. Eelko van Meerten, TNO Defence, Safety & Security
- OMk44 Gun/Ammo IPT, Maj Kirk D. Mullins, USMC, DRPM AAA
- O30mm Airburst Development - Translating Lessons Learned into System Requirements, Mr. Paul A. Reynolds, General Dynamics - OTS

Wednesday, 27 April 2005

**General Session:**

- ATEC Update, BG(P) James R. Myles, USA, Commanding General, US Army Test & Evaluation Command
- Raytheon Missile Systems: A Global Perspective, Mr. Robert Salyer, Director, Business Development Raytheon Missile Systems
- Acquisition and Sustainment Program, COL Lloyd E. McDaniels, USA, Project Manager, CCWS Project Office

**Session: Weapon Systems**

- Weapon System Concepts for a Future Gunship, Mr. Michael M. Canaday, Naval Surface Warfare Center
- Royal Navy Small Calibre Gun Research to Defeat the Small Boat Threat, Mr. Johnathan Watkins, Defence Scientific Technology Laboratory
- Mini-Typhoon Remote Operated Small Arms Mount (ROSAM), Mr. Benjamin J. Hardie, General Dynamics Armament and Technical Products
- Update on Picatinny High Speed Turret, Mr. Mr. Richard Ciekurs, US Army RDECOM-ARDEC
- 40mm CTWS Supporting UK and France, Mr. Michael Duckworth, CTA International

**Session: Missiles & Rockets**

- Abraham Overview, Mr. Robert Daunfeldt, Bofors Defence
- Summary Overview of an Advanced 2.75 Hypervelocity Weapon, Mr. Larry Bradford, CAT Flight Services, Inc
- APKWS Flight Test Results, Mr. Larry Ingram and Mr. Dean Slocum, General Dynamics Armament & Technology Products
- APKWS Block II Demonstration Program , Mr. Milton E. (Gene) Henderson, Jr., US Army RDECOM-AMRDEC
- Missile Systems Lethality Enhancement Through the Use of a Conducting Aerosol Plasma Warhead, Mr. Allen H. Stults, US Army RDECOM-AMRDEC
- Next Generation Adaptable RF Seekers for Precision Munitions, Dr. Cory Myers, BAE Systems IEWS
- Technology for the Smart Rocket Launcher: The System Enabler For The 21st Century, Mr. Donald E. Davis, US Research, Development & Engineering Command
- Development of a Unique Penetrator Warhead for Rocket or Missile Delivery, Mr. Roger W. Melin, Lockheed Martin Missiles and Fire Control

***Session: Large Caliber***

- Development of the M1028, 120mm Anti-Personnel Tank Round, Mr. Hugh MacMillan, US Army Armaments Research, Development & Engineering Center and Mr. Neal Hylton, General Dynamics – Ordnance and Tactical Systems
- Metallic Materials & Processes Enabling Lightweight System Initiatives, Mr. Jeff Lehner, Director, Military Programs, Alcoa/Howmet Corporation
- Advanced Modular Gun Demonstrator: Redefining – “Faster Than A Speeding Bullet”, Mr. Steve Coladonato, Applied Ordnance Technology, Inc.
- The Modified Tank Ammunition IMI M152/6 HEAT-AP- T, Mr. Danny Schirding, Chief Systems Engineer  
Tank Ammunition Directorate - IMI Ammunition Group
- A105/120/125 mm PELE Firing Results, Dr. Lutz Börngen, Rheinmetall Wafe Munition
- Line Of Sight/Beyond Line Of Sight (LOS/BLOS) Advanced Technology Demonstrator (ATD), Mr. David C. Smith, P.E., USA Benet Laboratories

***Session: Energetics***

- Development, Evaluation and Lifetime Prediction of Medium and Large Caliber Ammunition, Mr. Gert Scholtes, TNO
- Concepts and Practices in Finding and Applying Lessons Learned, Mr. David F. Fair, US Army ARDEC
- Propellant Replacement for the 105-mm M67 Propelling Charge, Ms. Adriana L. Eng, US Army ARDEC
- Lead Azide Replacement Program, Mr. John M. Hirlinger, US Army RDECOM-ARDEC
- Modeling Efforts for Autorotation Delivery System Concept Development, Mr. David C. Rutledge, Ph.D., Staff Engineer, United Defense

Thursday, 28 April 2005

***General Session:***

- Direct Fire Ammunition Lessons Learned: “More Than Just Impacts on Bullets”, COL Mark Rider, USA, Project Manager, Maneuver Ammunition Systems
- U.S. Army ARDEC Overview & Special Weapon Observation Reconnaissance Direct-Action System (SWORDS), Mr. Anthony Sebasto, Associate Director for Technology & Business Development, AETC
- National Defense Industrial Association (NDIA) Armament Division - 2005 Division Status, Mr. Dave Broden, Chairman, Armaments Division, NDIA

***Session: Technology & Manufacture***

- Automated Ammunition Identification, Mr. David F. Pouliot, United Defense L. P.
- Design for Manufacturing & Assembly (DFMA), Mr. Steve Watts, US Army RD&E Command
- ARDEC Business Development Process, Mr. David L. Burkhardt, Director, Strategic Communications, US Army ARDEC
- MEMS IMU – Common Guidance, Dr. Vicki C. LeFevre, US Army RDECOM-AMRDEC and Mr. David W. Panhorst US Army ARDEC, US Army ARDEC
- Development and Testing of High Explosive (HE) Projectiles for Electro-Magnetic Gun Army Tech Objective (ATO), Mr. Manfredi Luciano, US Army ARDEC
- Metal Injection Molding of Wing/Flaperon, Mr. Jerry C. LaSalle, Director of MIM Operations, Polymer Technologies, Inc (PTI)
- TBX Evaluation Testing in the M151 (2.75") Warhead as Risk Reduction for the APKWS, Mr. Jason C. Gilliam, US Army RDECOM-AMRDEC
- Archer Artillery Program, Mr. Ulf Einefors, Bofors Defence
- Improvements to Airborne Ladar Man-in-the-Loop Operations, Mrs. Sarah J. Hard, RDECOM-AMRDEC

***Session: Mortars & Artillery***

- M865 TID Improvement Study, Mr. Jason W. Gaines, General Dynamics
- Lessons Learned from the Development of the U.S. Navy 5-Inch Force Protection Projectiles, Mr. Sanford (Luke) Steelman, III, Naval Surface Warfare Center
- Advanced Gun Barrel Technologies, Dr. Amir Chaboki and Mr. Allen Boutz, United Defense
- Defining Homogeneity for Medium Caliber Ammunition and Small Grain Propellant Lots, Mr. Scott Carney, ATK
- Precision Fires for the Field Artillery, Mr. John Halvey, Raytheon, and Stefan Blomgren, Bofors Defence
- Low Cost Course Correction (LCCC) Demonstration Program, Mr. George Barnych and Mr. Daniel Davis, Ordnance and Tactical Systems Division
- XM395 Precision Guided Mortar Munition (120mm PGMM): Responsive, Standoff Precision Lethality for Highly Deployable and Mobile Forces, Mr. James Terhune and Mr. Anthony Pezzano, OPM Mortars
- Precision Guided Miniature Munitions, Mr. Mark Carlson, BAE Systems
- The 81mm Non Lethal Mortar Carrier Projectile (MoCaP), Mr. Seungeuk Han, Mr. Andrew Ponikowski, and Mr. Raymond Trohanowsky, US Army RDECOM-ARDEC
- Commercial Disposal of Explosive Wastes, Mr. Mark M. Zaugg, EBV Explosives Environmental Company



## *“Translating Lessons Learned into Systems Requirements”*

### **40th Annual Armament Systems: Guns - Ammunition - Rockets - Missiles Conference & Exhibition**

April 25 - 28, 2005

Sheraton New Orleans Hotel  
New Orleans, LA



## Monday, April 25 2005

- 10:00 a.m. On-site Registration
- Noon Exhibit Move-In
- 5:00 p.m. - Reception in the Exhibit Hall  
6:30 p.m.
- 6:30 p.m. Adjourn for the Day

## Tuesday, April 26, 2005

- 7:00 a.m. On-site Registration / Continental Breakfast
- 7:45 a.m. Opening Remarks
- 8:00 a.m. ***Mr. David C. Schulte***, Executive Director, Naval Ordnance Safety & Security Activity
- 8:30 a.m. ***Dr. James C. Bradas***, Associate Director for Missile Technology, AMRDEC
- 9:00 a.m. **Session: Modeling & Simulation**
- Accuracy Modeling of the 120mm M256 Gun as a Function of Bore Centerline Profile  
***Mr. David Smith for Dr. Ronald G. Gast***, Benet Laboratories
- Opening New DOORS to Managing JSF Gun System Requirements  
***Ms. Renee I. Bellack***, General Dynamics Armament and Technical Products
- Optimized Trajectory Shaping Guidance for an Air-to-Ground Missile Launched from a Gunship  
***Mr. Shane Sorenson***, Naval Surface Warfare Center
- 9:30 a.m. Exhibit Hall Opens
- 10:00 a.m. Break in the Exhibit Hall
- 10:30 a.m. Conceptual Weapon System Design for the Defense of Naval Vessels from the Swarming Small Boat Threat  
***Mr. John E. Bibel***, Naval Surface Warfare Center Dahlgren Division
- Warhead Penetration Dynamics - Warhead Body, Fuze, and Target Interaction  
***Mr. Richard Ventura***, Talley Defense Systems
- Ballistic Limits of Skin and Clothing for Lethality Estimates of Projectiles Wound Ballistics  
***Mr. Henry E. Hudgins***, US Army ARDEC
- A Review of the Recent NIMIC IM Design Technology Workshop  
***Mr. M. Pascal Marchandin***, NATO - MSIAC
- 11:50 a.m. Luncheon: Super Weapons From a Historical and Psychological Basis  
***LTC Simon R. West***, British Army, United Kingdom Defence Academy

- 1:10 p.m.      **Session: Medium Caliber Systems**
- Ammunition for the New Infantry Battelfield Environment  
*Mr. Allan N. Buckley*, BTECH Oerlikon Contraves Pyrotec AG
- Force Protection - Multi Mission Vehicle Armament & Air Burst Munition for Expeditionary Warfare  
*Mr. Andrew Bradick*, Lockheed Martin
- F-35 Joint Strike Fighter Gun Overview and System Update  
*Mr. David L. Maher* and *Mr. Douglass C. Parker*, General Dynamics, Armament and Technical Products
- Phalanx Targeting Investigation  
*Mr. Jeff A. Siewart*, Arrow Tech Association
- 3:00 p.m.      Break in the Exhibit Hall
- 3:30 p.m.      **Session: Medium Caliber Systems (Continued)**
- Mk 110 Mod 0 / 57mm Gun Test & Certification Process  
*LT Timothy J. Hackett, USCG*, US Coast Guard
- GAU-19/A Barrel Life Study  
*Mr. James J. St. Germain*, General Dynamics Armament & Technology Products
- Calibre Choice for the Dutch IFV  
*Mr. Eelko van Meerten*, TNO Defence, Safety & Security
- The Expeditionary Fighting Vehicle, How Operational and Combat Lessons Learned Apply to the EFV and the 30MM Mix of Tomorrows Warfighter  
*Maj Kirk D. Mullins, USMC*, DRPM AAA
- 30x173mm HEAB-T Development and Lessons Learned  
*Mr. Paul A. Reynolds*, General Dynamics - OTS
- 5:30 p.m. - 7:00 p.m.      Reception in the Exhibit Hall
- 7:00 p.m.      Adjourn for the Day

**Wednesday, April 27, 2005**

- 7:00 a.m.      On-site Registration / Continental Breakfast
- 7:45 a.m.      Opening Remarks
- 8:00 a.m.      *BG (P) James R. Myles, USA*, Commanding General, US Army Test & Evaluation Command
- 8:45 a.m.      *Mr. Robert Salyer*, Raytheon
- 9:10 a.m.      Acquiring and Sustaining US Army Missiles  
*COL Lloyd E. McDaniels, USA*, CCWS Project Office

9:30 a.m. Exhibit Hall Opens

9:45 a.m. **Session: Medium Caliber Systems (Continued)**

Recent Developments of the M230 30MM Chain Gun  
**Mr. Lawrence A. Mason**, ATK Ordnance & Ground Systems

MK44 Automatic Cannon Update  
**Mr. Mark McMillian**, ATK Ordnance Systems

10:30 a.m. Break in the Exhibit Hall

### Concurrent Sessions

10:50 a.m. **Session: Weapon Systems**

AC-130U Gun System Production Re-Start  
**Mr. John G. Fletcher**, General Dynamics Armament and Technical Products

Weapon System Concepts for a Future Gunship  
**Mr. Michael M. Canaday**, Naval Surface Warfare Center

Royal Navy Small Calibre Gun Research to Defeat the Small Boat Threat  
**Mr. Johnathan Watkins**, Defence Scientific Technology Laboratory

11:50 a.m. - Lunch

1:00 p.m. **Session: Weapon Systems (Continued)**

Remote Operated Small Arms Mount (ROSAM)  
**Mr. Benjamin J. Hardie**, General Dynamics Armament and Technical Products

Placing Gunner's Behind the Protective Armor of Vehicles  
**LTC Kevin P. Stoddard, USA**, PM Soldier Weapons

Picatinny High Speed Turret (PHIST)  
**Mr. Richard Ciekurs**, US Army RDECOM-ARDEC

**Session: Missiles & Rockets**

Critical Asset Defense - ABRAHAM Rocket Assisted Projectile  
**Mr. Robert Daunfeldt**, Bofors Defence

Hypervelocity Propulsion System Substantially Improves 2.75 Rocket Lethality, Safety, Survivability  
**Mr. Larry Bradford**, CAT Flight Services, Inc.

APKWS Flight Test Results  
**Mr. Larry S. Ingram**, General Dynamics Armament and Technical Products

APKWS Block II Demonstration Program  
**Mr. Milton E. (Gene) Henderson, Jr.**, US Army RDECOM-AMRDEC

Lunch

**Session: Missiles & Rockets (Continued)**

Missile System Lethality Enhancement Through the Use of Pulsed Power and Plasma Conduction  
**Mr. Allen H. Stults**, US Army RDECOM

Next Generation Adaptable RF Seekers for Precision Munitions  
**Dr. Cory Myers**, BAE Systems

The Smart Rocket Launcher as the Key Enabler for the Rocket System of the Future: The Technology Developments Needed for the Next Generation Rocket Launcher to Carry 70mm Rockets into the 21st Century  
**Mr. Donald E. Davis**, US Army Research, Development & Engineering Command

### Session: Weapon Systems (Continued)

Recent Activities Involving 40mm CTWS in Support of UK and France  
**Mr. Michael Duckworth**, CTA International

The Marine Corps Expeditionary Fire Support System (EFSS): A Systems Overview  
**Mr. Jason Burkett**, General Dynamics

2:40 p.m. Break in the Exhibit Hall  
(*Last Opportunity to Visit Exhibits*)

3:00 p.m. Exhibit Hall Closed

3:10 p.m. **Session: Large Caliber**

Development of the XM1028, 120mm Anti-Personnel Tank Round  
**Mr. Hugh MacMillan**, Armaments Engineering and Technology Center, **Mr. Peter Georgantzis**, US Army ARDEC, and **Mr. Neal Hylton**, General Dynamics-OTS

Titanium Investment Casting Weapon System Application  
**Mr. Jeff Lehner**, Director, Military Programs, Alcoa/Howmet Corporation

Advanced Modular Gun Demonstrator - XLT Test Gun  
**Mr. Steve Coladonato**, Applied Ordnance Technology, Inc.

The Modified Ammunition, Equipped with the "Fuzaman": The IMI 105-mm Heat-AP-t Cartridge M152/6  
**Mr. Danny Schirding**, Israel Military Industries, Ltd

105/120/125 mm PELE Firing Results  
**Dr. Lutz Borngen**, Rheinmetall Waffe Munition

Lightweight Gun Development and Testing for the Future Combat System  
**Mr. David C. Smith, P.E.**, USA Benet Laboratories

5:15 p.m. Adjourn for the Day

### Session: Missiles & Rockets (Continued)

Development of a Unique Penetrator Warhead for Rocket or Missile Delivery  
**Mr. Roger W. Melin**, Lockheed Martin Missiles and Fire Control

Determining the Army Aviation Rocket and Missile Mix for the Future Fight  
**Mr. William M. Mulholland**, Whitney, Bradley & Brown

Break in the Exhibit Hall  
(*Last Opportunity to Visit Exhibits*)

Exhibit Hall Closed

**Session: Energetics**

Advanced Propelling Solutions Complying with Demands (FCS)  
**Dr. Beat Vogelsanger**, NITROCHEMIE Wimmis AG

Development, Evaluation and Lifetime Prediction of Medium and Large Caliber Ammunition  
**Mr. Gert Scholtes**, TNO

Concepts and Practice in the Application of Lessons Learned  
**Mr. David F. Fair**, US Army ARDEC

Propellant Replacement for the 105-mm Artillery Propelling Charge  
**Ms. Adriana L. Eng**, US Army ARDEC

Environmentally Benign Substitute Compounds for Lead Azide  
**Mr. John M. Hirlinger**, US Army RDECOM-ARDEC

Modeling Efforts in Support of PKERS Concept Development  
**Mr. David C. Rutledge, Ph.D.**, Staff Engineer, United Defense

Adjourn for the Day

**Thursday, April 28, 2005**

- 7:00 a.m. On-site Registration / Continental Breakfast
- 7:45 a.m. Opening Remarks
- 8:00 a.m. **COL Mark Rider, USA**, Project Manager, Maneuver Ammunition Systems
- 8:30 a.m. **Mr. Anthony Sebasto**, Associate Director for Technology & Business Development, AETC
- 9:00 a.m. **Mr. Dave Broden**, NDIA Armaments Division Status Overview, Chairman, Armaments Division, NDIA
- 9:20 a.m. Break

**Concurrent Sessions**

**9:40 a.m. Session: Technology & Manufacture**

Automated Ammunition Identification  
**Mr. David F. Pouliot**, United Defense L. P.

Deep Digger Weapons System Concept  
**Mr. David W. Burns**, US Army ARDEC

Development of Composite Launch Tubes for  
Shoulder Fired Weapons through Applied  
Science, Planning and Teamwork  
**Mr. Thomas P. Jacobson**, Talley Defense  
Systems

Design for Manufacture & Assembly (DFMA)  
**Mr. Steve Watts**, US Army RD&E Command

Technology and Manufacturing Initiatives  
**Mr. Dave Burkhardt**, Enterprise Management  
Office, US Army ARDEC

**Session: Technology & Manufacture  
(Continued)**

Army MEMS Common Guidance Program  
**Mr. David. W. Panhorst**, US Army ARDEC  
and **Dr. Vicki C. LeFevre**, AMRDEC

Development and Testing of HE Projectiles for  
EM Gun - STO  
**Mr. Manfredi Luciano**, US Army ARDEC

**Session: Mortars & Artillery**

Tank 120mm Training Ammunition: MB65 Target  
Impact Dispersion Study  
**Mr. Jason W. Gaines**, General Dynamics-  
OTS

Lessons Learned from the Development of the U.S.  
Navy 5-inch Ship Self Defense Projectiles  
**Mr. Sanford L. Steelman, III**, Naval Surface  
Warfare Center

ONR's Advanced Gun Barrel Technology Program  
**Mr. Allen Boutz**, United Defense

Structural Margin Improvement on the M829A3  
Projectile  
**Mr. Scott Carney**, ATK

**Session: Mortars & Artillery**

Excalibur: Turning the Field Artillery into a Long  
Range Precision Attack Weapon System  
**Mr. Stefan Blomgren**, Bofors Defence

Low Cost Course Correction (LCCC)  
Demonstration Program  
**Mr. George B. Barnych**, General Dynamics  
Ordnance and Tactical Systems Division

**Session: Technology & Manufacture  
(Continued)**

Advanced Metal Injection Molding Technology  
Applications to Defense Industry  
**Mr. Jerry LaSalle**, Polymar Technologies

11:40 a.m. Lunch

1:00 p.m. **Session: Technology & Manufacture  
(Continued)**

TBX Evaluation Testing in the M151 (2.75")  
Warhead as Risk Reduction for the APKWS  
**Mr. Jason C. Gilliam**, US Army RDECOM-  
AMRDEC

Advanced Precision Kill Weapon System  
**Mr. Ulf Einefors**, Bofors Defence

Test Results of an Imaging LADAR Seeker for  
Small Missiles  
**Mrs. Sarah J. Hard**, RDECOM-AMRDEC

**Session: Mortars & Artillery  
(Continued)**

Applying Six Sigma Principles to Implementation  
of the PGMM Training Concept  
**Mr. Anthony Pezzano**, OPM Mortars

Lunch

**Session: Mortars & Artillery (Continued)**

Precision Guided Miniature Munitions  
**Mr. Mark Carlson**, BAE Systems

Development of a Non-Lethal Mortar Delivery  
System  
**Mr. Seungeuk Han**, US Army RDECOM-  
ARDEC and **Mr. Andrew Ponikowski**, US  
Army, RDECOM-ARDEC

Explosive Waste Recycle and Disposal  
**Mr. Mark M. Zaugg**, EBV Explosives  
Environmental Company

3:00 p.m. **Conference Adjourns**



# ***Development of a Unique Penetrator Warhead for Rocket or Missile Delivery***



***Presented to:  
National Defense Industrial Association 40th Annual Armament  
Systems: Guns - Ammunition - Rockets – Missiles (GARM)  
Conference & Exhibition***

***25 – 28 April 2005***

***Roger W. Melin***

***Lockheed Martin Missiles and Fire Control  
roger.melin@lmco.com  
(972) 603-1769***

- **I-NAIL™ Penetrator Concept**
- **I-NAIL™ Penetrator Design**
- **Recent Testing**
  - **Penetration Tests**
  - **Static Expulsion Tests**
  - **Wind Tunnel Expulsion Tests**

# ***I-NAIL™ Project Introduction***

*Missiles and Fire Control*

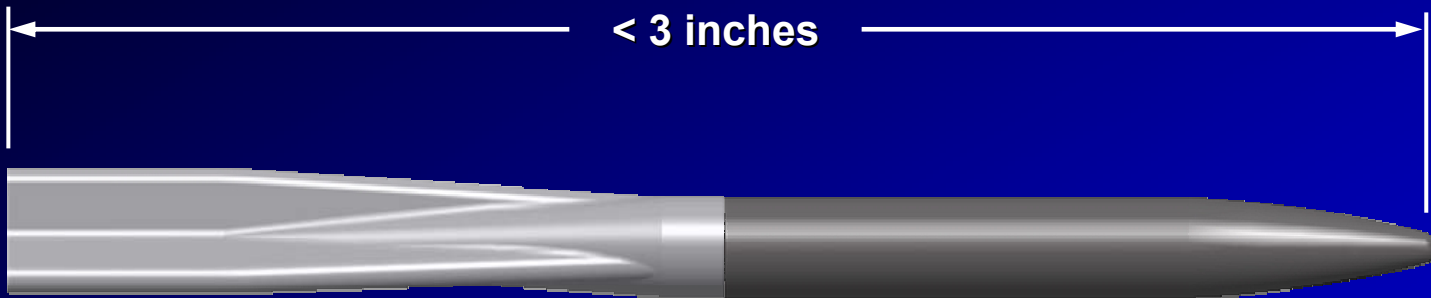
- **Project began as alternate GMLRS/HIMARS payload**
  - ✓ Zero dud rate
  - ✓ Inexpensive
  - ✓ Increased lethality
  - ✓ Limited zone of effects
- **Alternate platforms & applications**
  - ✓ Hydra-70
  - ✓ APKWS
  - ✓ AC –130 Gunship (105 mm cannon)



# I-NAIL™ Penetrator

Missiles and Fire Control

## Assembled Configuration



Tail

Injected molded plastic

Forebody

Tungsten Alloy

## Forebody



# ***I-NAIL™ Penetrator Design Trades***

*Missiles and Fire Control*



## ***Testing***

### **Forebody Materials**

- Ceracom 2
- Ceracom 3 hipped
- Ceracom C116
- Ceracom - not hipped
- French Sintered Rod
- French Swaged Bar
- Hawk (Formulas 1 – 3)
- HD17 Tungsten Bar
- HD17D Tungsten Bar
- Liquid Metal
- Sintered Tungsten
- Tungsten Welding Rod

### **Tail Materials**

- Aluminum
- Magnesium
- Plastic
- Mischmetal (cerium & lanthanum)

### **Penetrator Masses**

- 150 – 300 grains

### **Target Materials**

- Al 5083
- Al 6061T6
- A36 Steel
- High Hard Armor
- Cast Iron Engine Manifold
- Concrete block
- Cinderblock Wall Simulant
- Flak Jacket
- Ballistic Gelatin

### **Impact Velocities**

- 750 – 2000 f/s

## ***Analysis***

### **Penetrator Masses**

- 150 – 300 grains

### **Forebody Geometry**

- Nose Shape
  - Circular Ogive
  - Von Karman (3:1 - 1:1)
- Shaft Cross Section
  - Circular
  - Hexagonal
- Tip Radii
  - Flat
  - Hemispherical

### **Impact Velocities**

- 750 – 2000 f/s

## **Business Development / Demo Tests**

- Performed in conjunction with tungsten evaluations
- Variety of targets, penetrator designs, and impact conditions

## **Engineering Tests**

- Performed to develop structured database
- Design of Experiments techniques used to design test matrix
- Results used to develop regression-based penetration predictors

# LMMFC Light Gas Gun Facility

Missiles and Fire Control

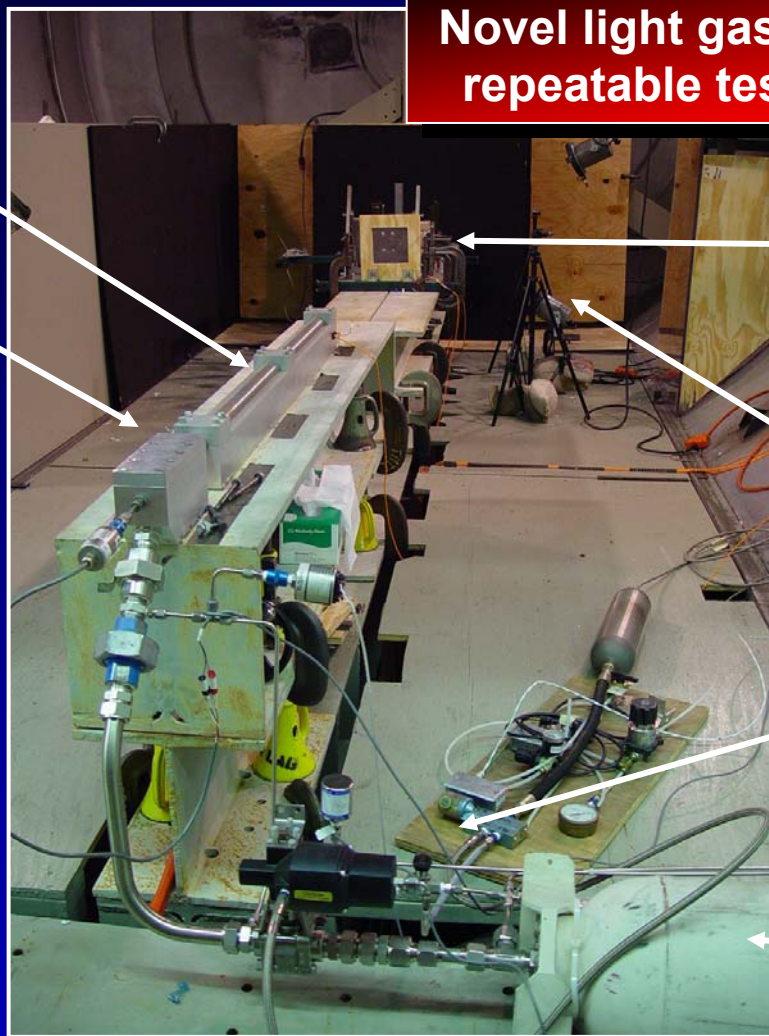


Gas (He) Gun

Breech



Data Acquisition/Data  
Reduction System



Novel light gas gun provides  
repeatable test conditions.

Make Screens/  
Target

Lighting/High  
Speed Cameras

Gas Retention  
Valve

Gas Plenum

# Representative Targets

**Light Armor**



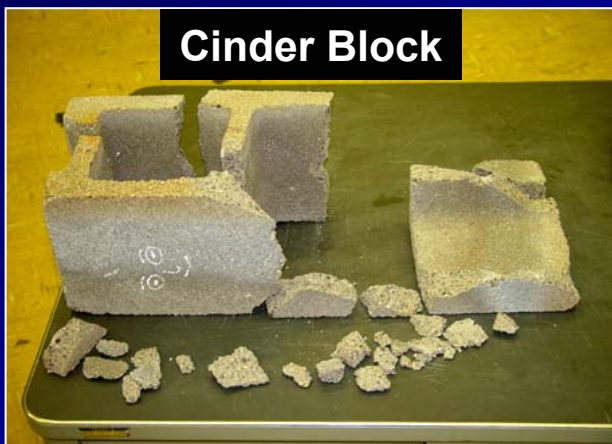
**Ballistic Gel**



**Flak Jacket**



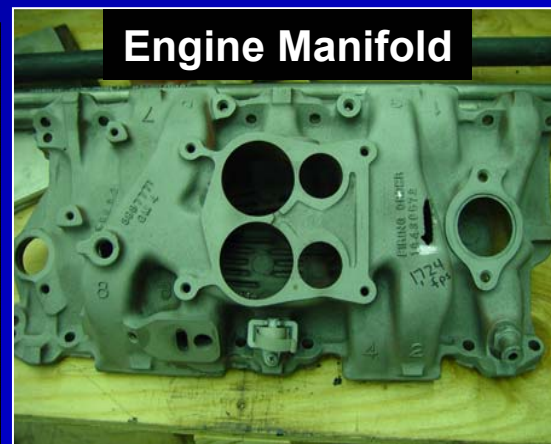
**Cinder Block**



**Concrete**

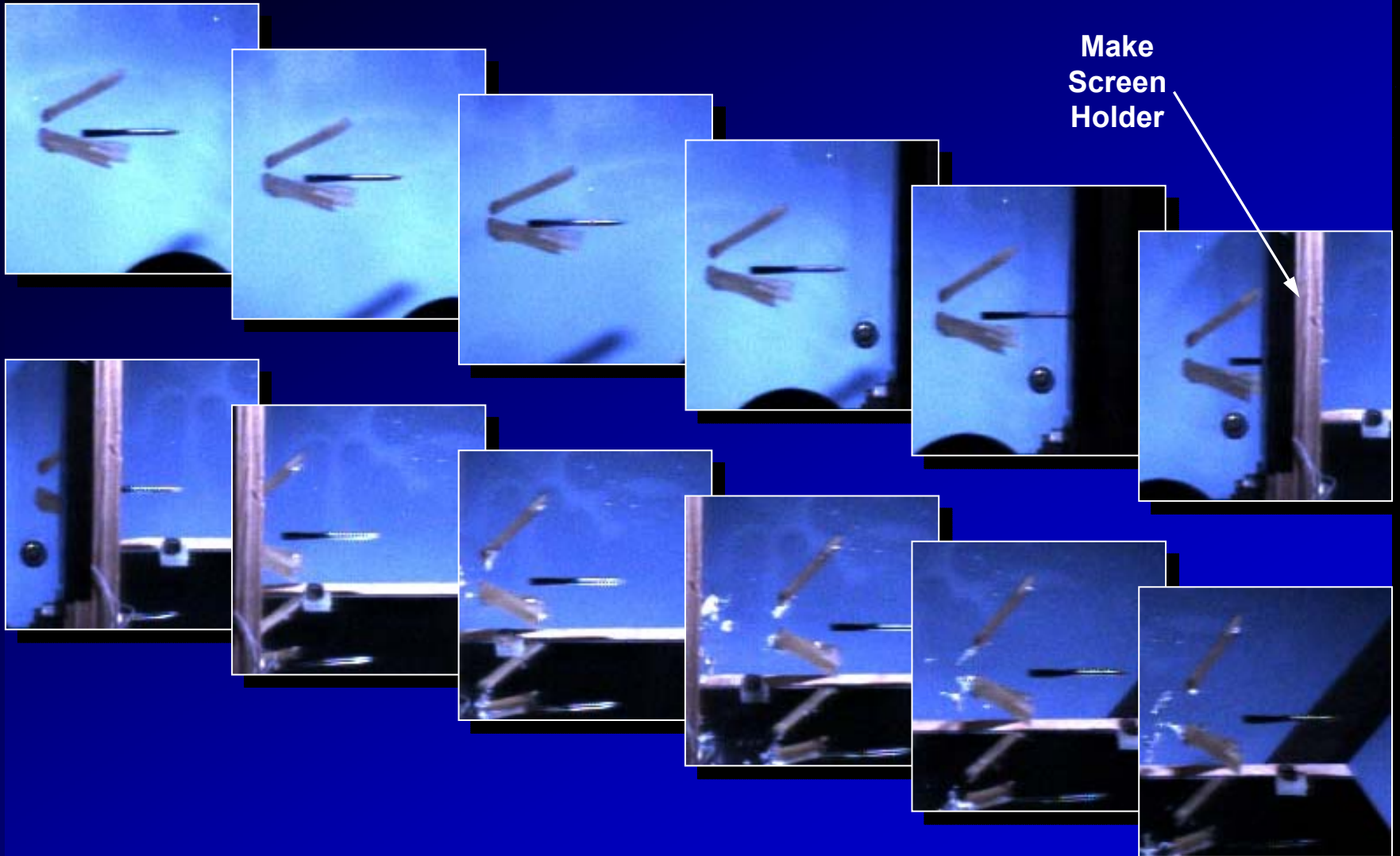


**Engine Manifold**



# ***I-NAIL™ Sabot Separation***

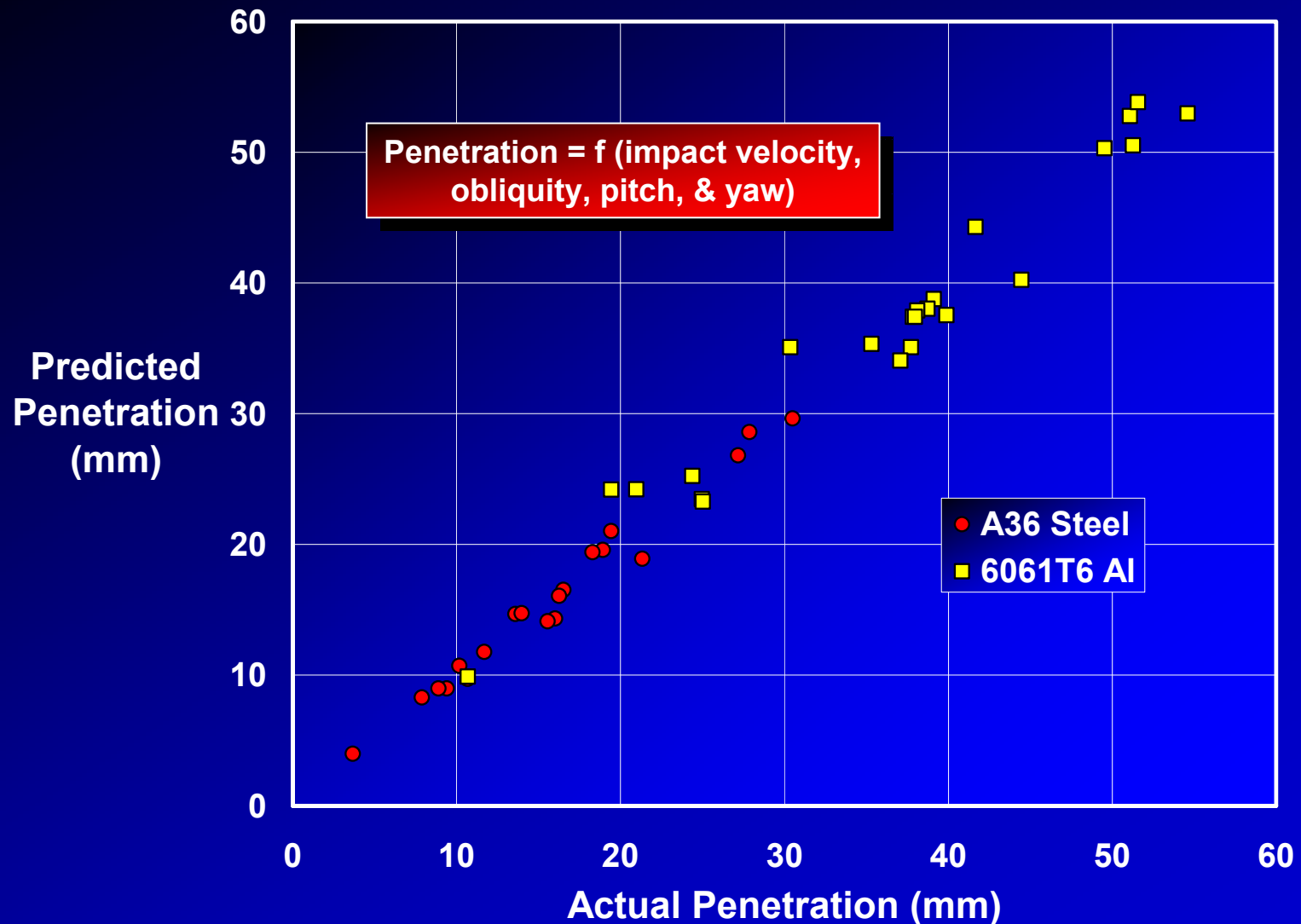
*Missiles and Fire Control*



Make  
Screen  
Holder

# I-NAIL™ Penetration Modeling

Missiles and Fire Control



## **Objectives:**

- **Package maximum loadout of I-NAIL™ penetrators maintaining HYDRA-70 weight / CG requirements**
- **Design and demonstrate performance of dunnage / penetrator support mechanism**
- **Demonstrate successful expulsion of I-NAIL™ penetrator payload with Hydra-70 expulsion charge**
- **Expulsion velocity ~150 f/s**

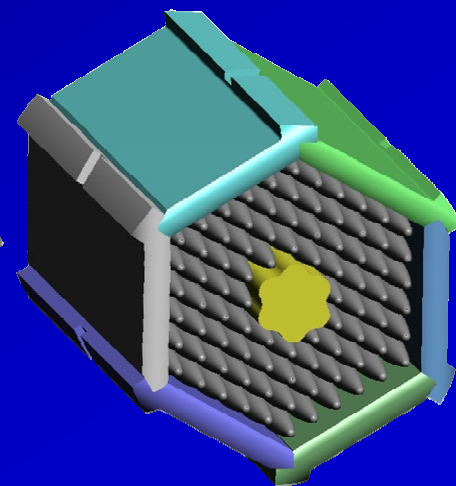
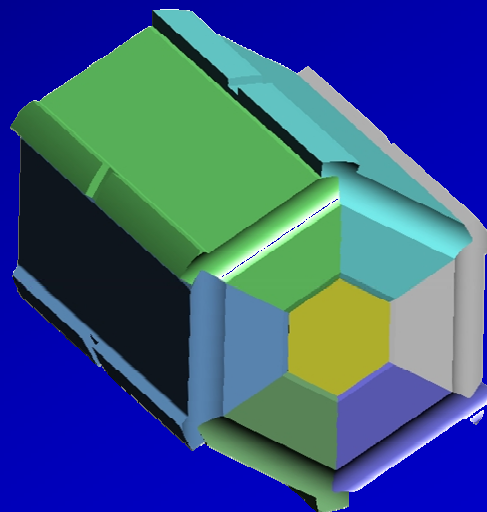
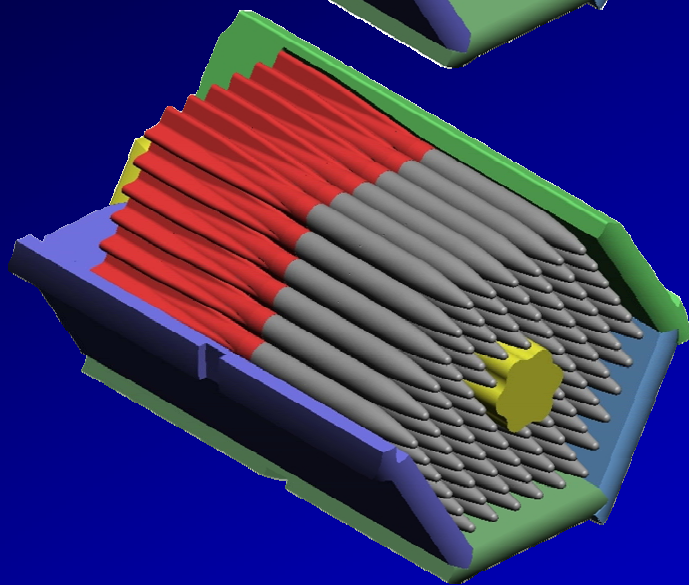
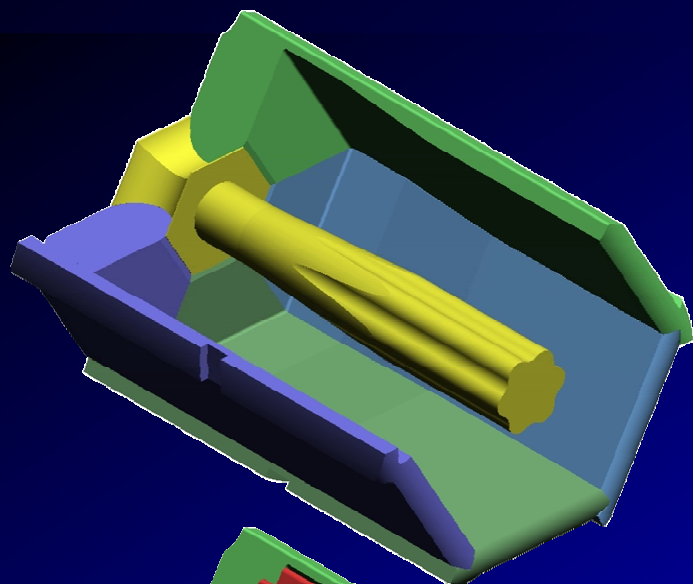
A collection of 3D CAD models of various mechanical components, including cylindrical housings, internal assemblies with fans or filters, and structural frames, all rendered in different colors (green, blue, yellow, red, grey) against a black background.

# ***Selected Hydra-70 Dunnage Concept***

*Missiles and Fire Control*



- 6-petal design
- Peels apart like banana
- Center post takes loads of adjacent penetrator stacks
- Injection molded plastic

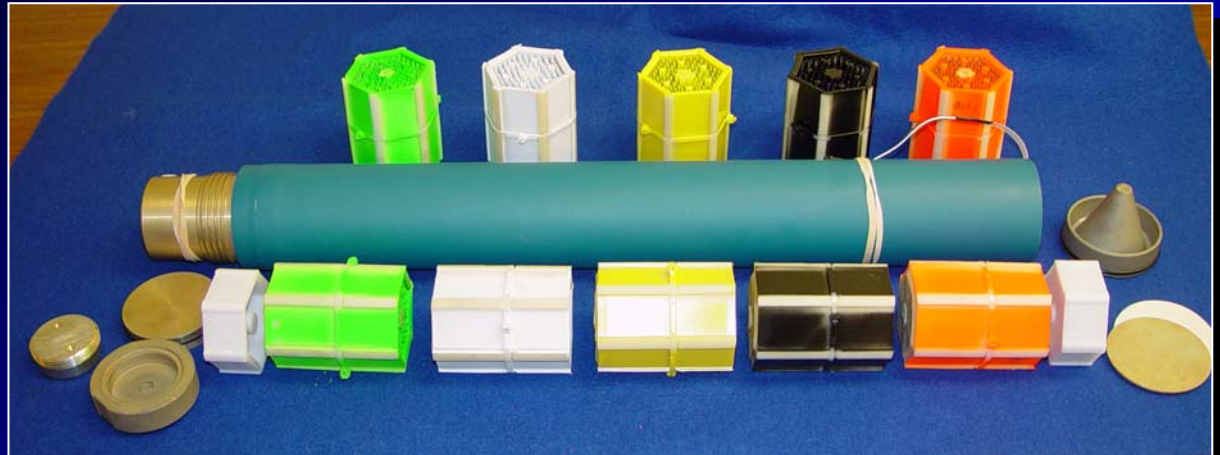


# Expulsion Test Hardware

  
Missiles and Fire Control



Forward end of Cup



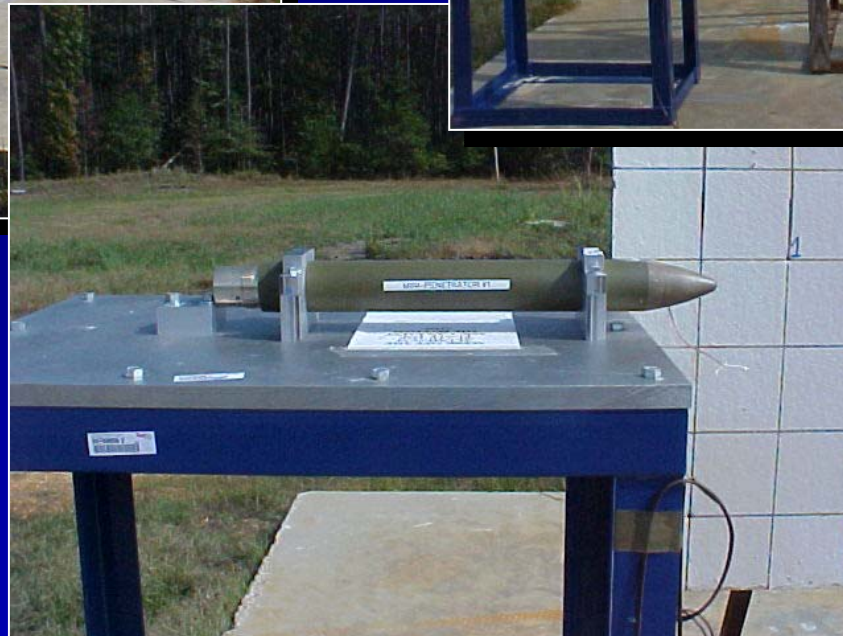
Aft end of Cup

- 390 I-NAIL™ penetrators/warhead + 30 simulants for mass matching
- Fore & aft spacers added for CG match
- 6-Petal dunnage design for support and penetrator release
- GFE Hydra-70 expulsion charge
- Special SAF to allow static function

- **Two Hydra-70 warhead casings loaded at Camden, AR facility with I-NAIL™ penetrators**
- **Two warhead tests performed on 20 October 2004 at National Technical Systems site in Camden, AR**
- **Static fired two warheads**
  - **No representative rocket airflow**
  - **No spin**
- **Three high-speed digital cameras used for data acquisition (2.1K frames/sec)**
- **Celotex package positioned down range for possible pattern data**

# Expulsion Test Layout

Missiles and Fire Control



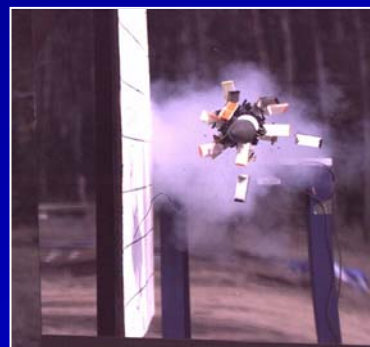
# Down-Bore Views



Test 1

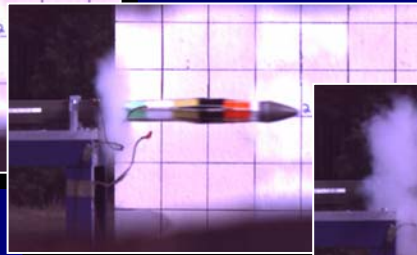
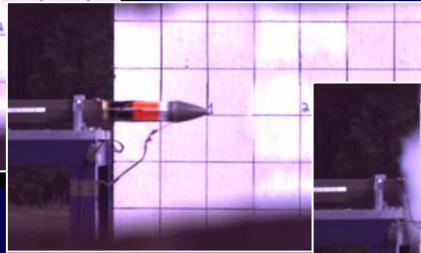


Test 2

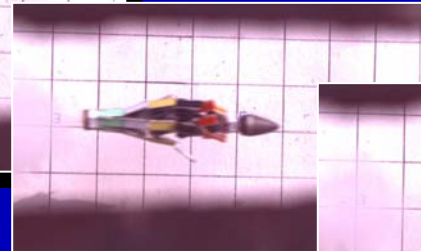
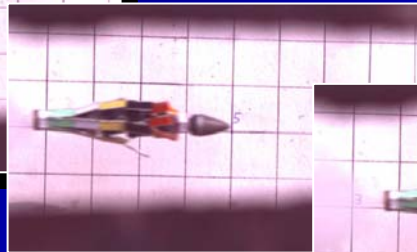
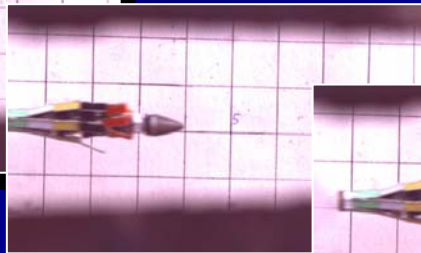
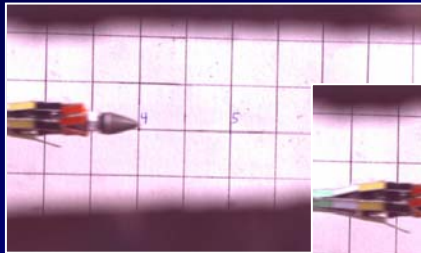


# Side View – Test 2

Missiles and Fire Control



$V = 139.5 \text{ f/s}$



$V = 138.2 \text{ f/s}$

# ***Expulsion Test Results Summary***

 Missiles and Fire Control

- **Both payloads successfully ejected**
- **Nominal ejection velocities achieved in both tests**
  - Test 1: Camera 1 – no data**  
**Camera 2 – 138.3 f/s**
  - Test 2: Camera 1 – 139.5 f/s**  
**Camera 2 – 138.2 f/s**
- **Most penetrator damage occurred from sideways impacts as opposed to expulsion event**
- **Actual flight conditions will minimize such effect since penetrators will have time to align correctly**
- **Penetrator ballistics as expected**

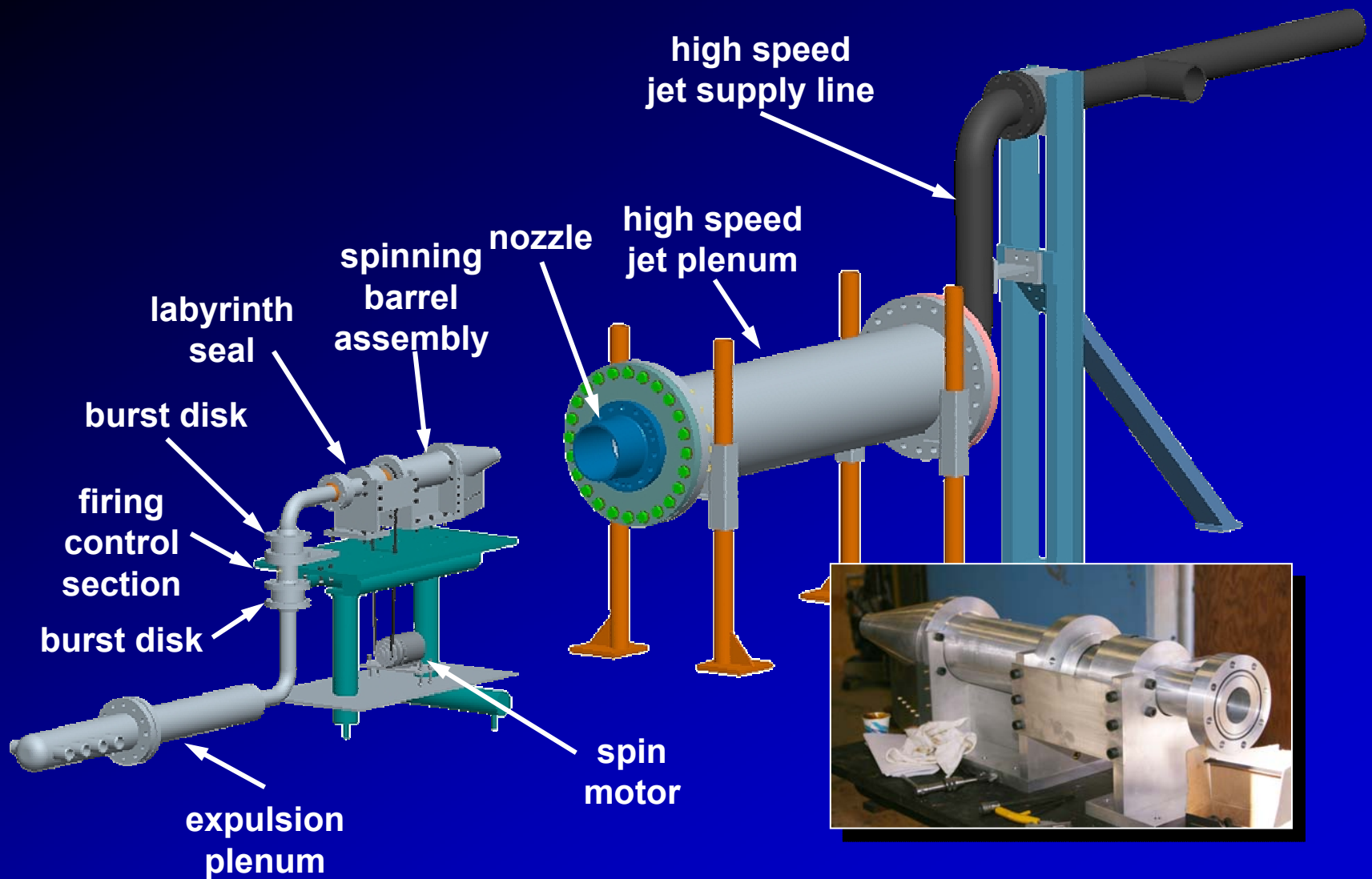
## **Objectives:**

- **Demonstrate separation cleanliness of two potential I-NAIL<sup>TM</sup> dunnage designs**
  - **6-Petal Design (Hydra-70)**
  - **3-Compartment Design (APKWS)**
- **Gather initial conditions for possible use in future dispense and pattern simulation studies**

- **Testing performed at LMMFC High Speed Wind Tunnel (HSWT) facility in Grand Prairie, TX on 18 December 2004**
- **“Backyard” Tests – High velocity flow ducted out of high pressure tanks to external test location**
- **Spinning air gun constructed to expel payload into high mass flow air stream**
- **Payloads represented two I-NAIL™ penetrator pack concepts**
  - **5 packs present in M255-A1 Hydra-70**
  - **3 packs present in APKWS**

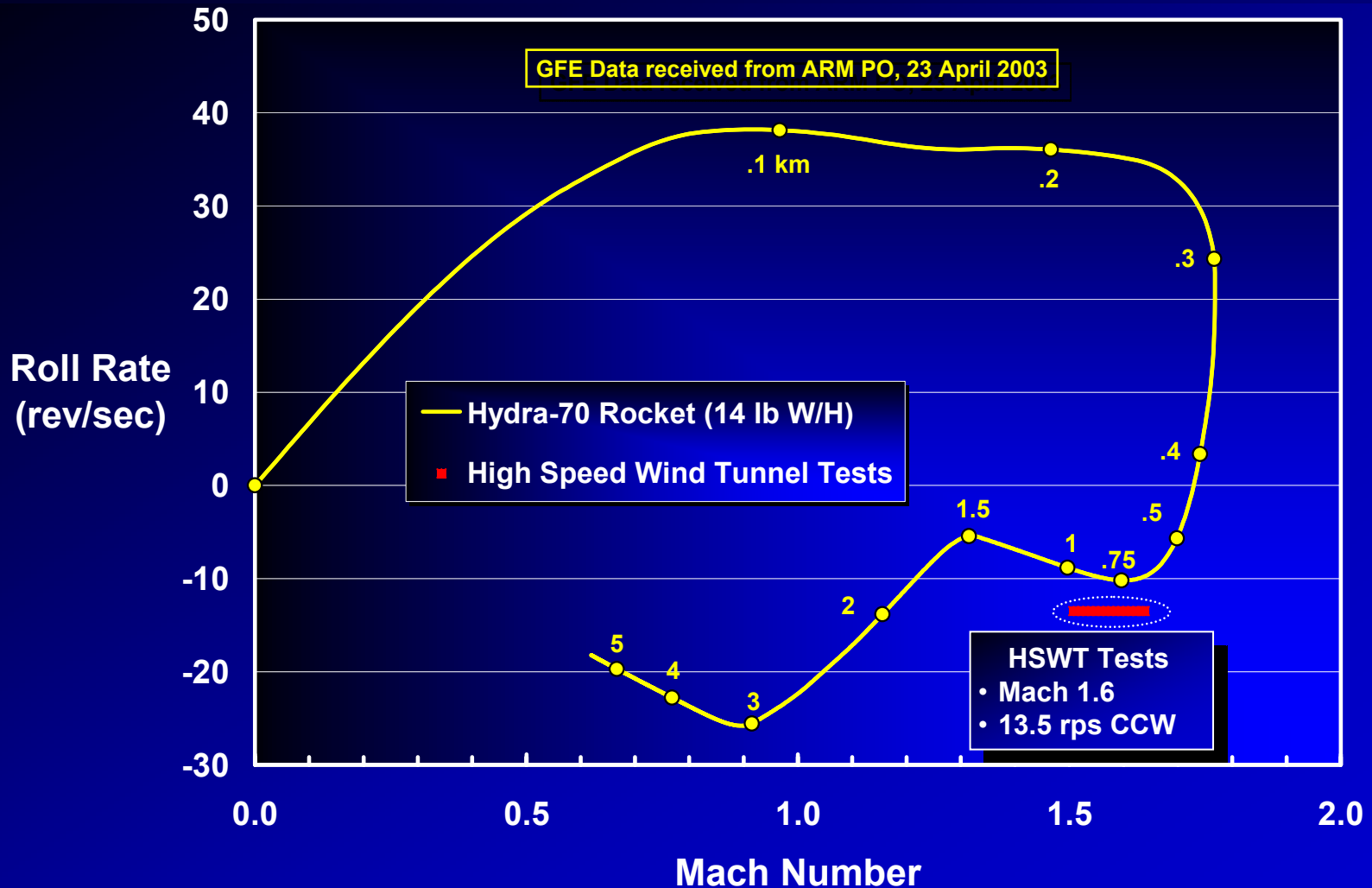
# Wind Tunnel Test Setup

Missiles and Fire Control



# I-NAIL™ Wind Tunnel Test Conditions

Missiles and Fire Control

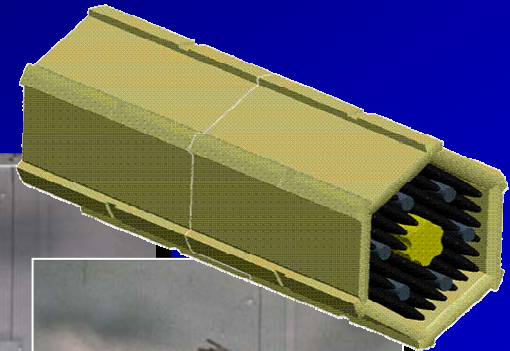


# I-NAIL™ Wind Tunnel Test 1

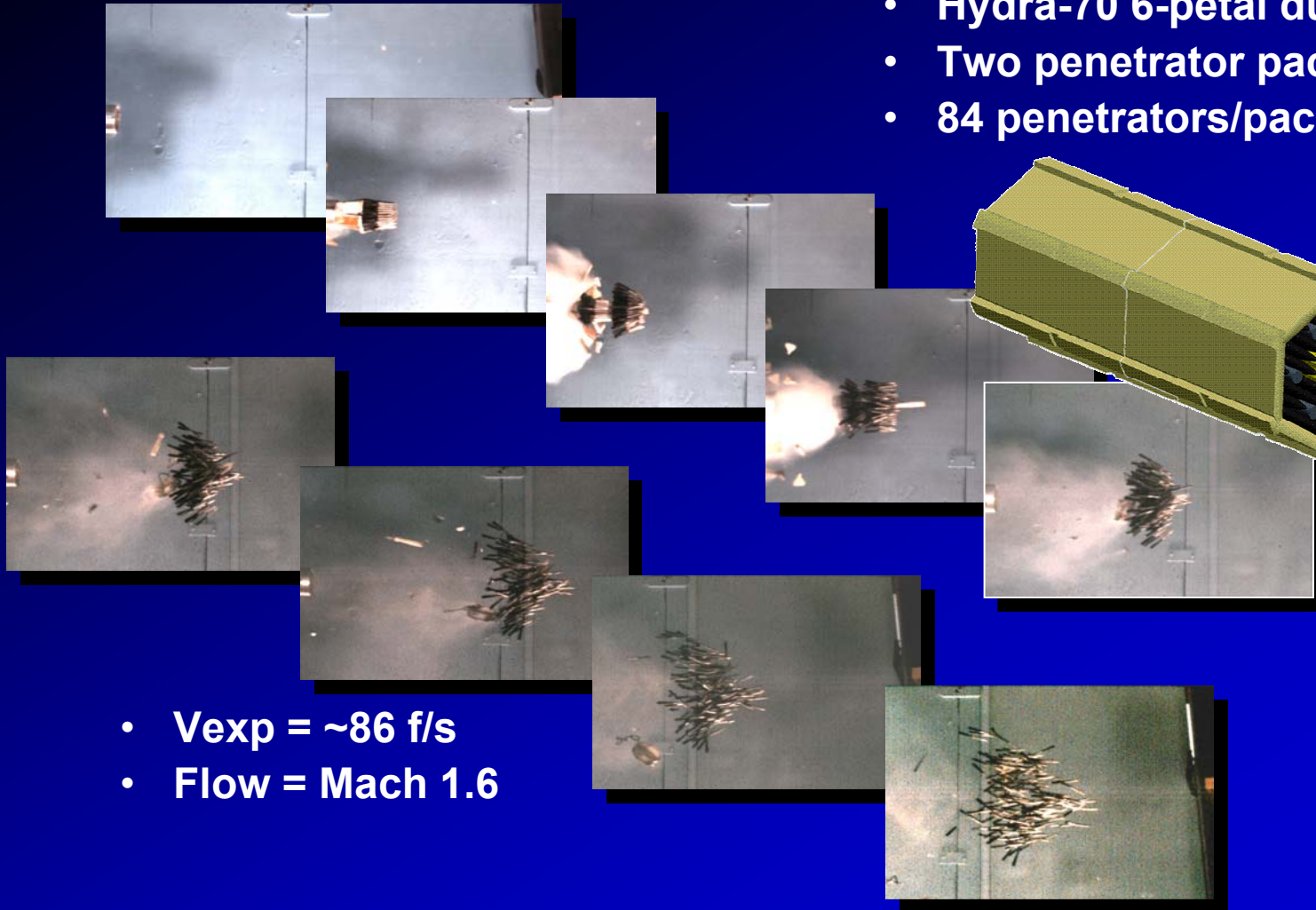
Missiles and Fire Control



- Hydra-70 6-petal dunnage
- Two penetrator packs
- 84 penetrators/pack



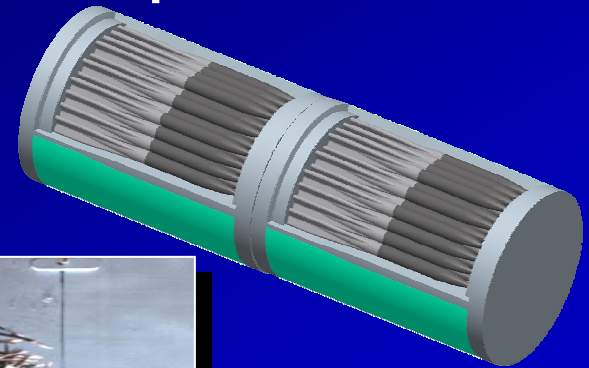
- $V_{exp} = \sim 86 \text{ f/s}$
- Flow = Mach 1.6



# I-NAIL™ Wind Tunnel Test 2

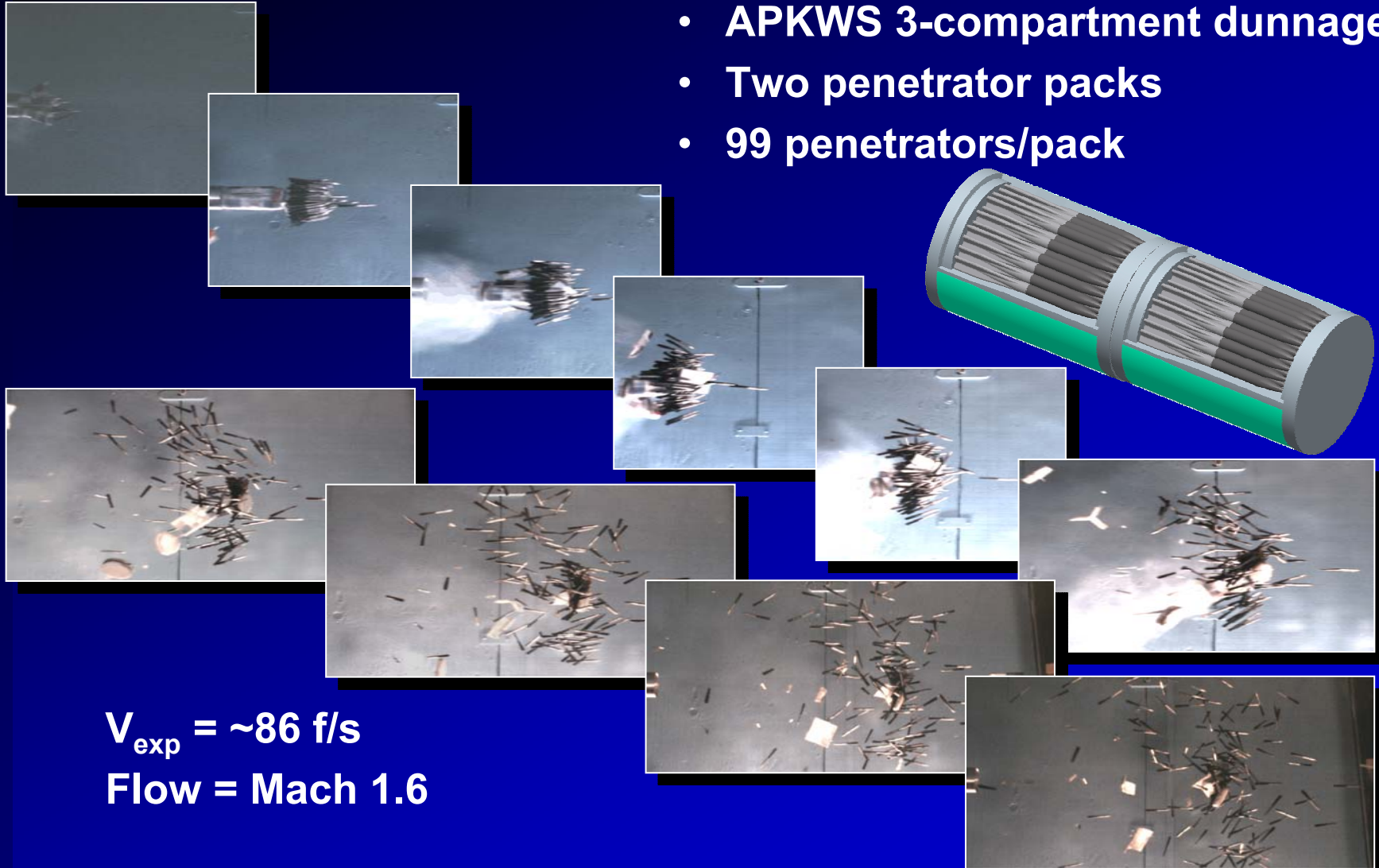
Missiles and Fire Control

- APKWS 3-compartment dunnage
- Two penetrator packs
- 99 penetrators/pack



$V_{\text{exp}} = \sim 86 \text{ f/s}$

Flow = Mach 1.6



# ***I-NAIL™ Dunnage Comparison***

 **Missiles and Fire Control**

## **6-Petal Dunnage Concept**

- Good release achieved
- Petals broke in a desired fashion and moved away quickly

## **3-Compartment Dunnage Concept**

- Center structure interferes with radial dispense of penetrators
- Compartment covers and solid forward plate are pushed into penetrator cloud

## **Both Concepts**

- Collisions occurred between two penetrator packs
- Second pack catches up to first mainly due to still being pushed by plenum gas; drafting effects may contribute
- Good penetrator dispersion and aerodynamics

# ***Wind Tunnel Test Conclusions***

*Missiles and Fire Control*



## **Dunnage**

- **6-Petal dunnage design preferred**
  - **Demonstrated better overall performance**
  - **Compatible with Hydra-70 and APKWS platforms**
  - **Utilizes existing M255-A1 components**
  - **Inexpensive solution for APKWS**

## **Penetrators**

- **Design has been modified to strengthen weak point in tail attachment section to minimize breakage**

**Viable dunnage concept has been tested and is ready for integration and flight testing.**

- **Mini-penetrator design developed**
  - **Design provides significant behind-armor effects**
  - **Highly lethal with no unexploded ordnance left on the battlefield**
  - **System integration approach and implementation demonstrated**
  - **Compatible with a variety of delivery systems**
- 

An abstract background on the left side of the slide featuring several overlapping circles and arcs in various shades of gray, creating a complex geometric pattern.

# **Next Generation Adaptable RF Seekers for Precision Munitions**

**40th Annual Guns-  
Ammunition-Rockets-  
Missiles Conference**

**Missiles & Rockets Session**

**April 27, 2005**

**Dr. Cory Myers  
BAE Systems IEWS  
cory.s.myers@baesystems.com**



- Provide small unit of operations with organic Precision Strike capability against High Value Targets
- Accelerate Enemy Defeat
- Reduce Collateral Damage
- Improve Deployability & Logistics
- RF Guided Munition (RFGM)
  - Provide a low cost precision means for ground forces to engage C3 targets, enemy FOs, and some radars
  - Completes the sensor-to-shooter chain for IO targets operating from 30MHz to 3GHz



***Current Mortar Munitions generally do not achieve first shot direct hit on target. RFGM guidance system capable of correcting trajectory improves first-shot hit on the target to 50%.***

# System Concept

- **Exploit dismounted, close-in attack scenario with small aperture, RF seeking weapon**
  - If the dismount (SOF) can be cued to the presence of the emitter then the dismount can attack the (soft target) emitter with an organic weapon (e.g. 81 mm mortar)
- **Create a passive, all-weather, and inexpensive precision RF seeker capability for multiple weapon types**
  - Enable a suite of precision and area suppression weapons (ground-to-ground, ground-to-air, and air-to-ground) that home on RF energy all using similar RF seeker and guidance technology
- **Deny enemy use of RF spectrum for military purposes**
  - Counter enemy radar/IR/acoustic signals Camouflage, Concealment and Deception (CCD) efforts

**DARPA Hard Technical Challenge: Quick and Precise Geo-location of RF Emitters from a Single, High-Velocity, Small Weapon**

## System Requirements:

- ***Quick:*** Geo-location estimate must be fast enough (5 sec) to guide a mortar which has only 25-30 seconds of flight time
- ***Precise:*** Geo-location with an objective radius of an 81 mm mortar (20 m)
- ***RF Emitters:*** Target frequencies from 30 MHz to 3 GHz and multiple waveforms
- ***Single:*** Emissions received by only a single platform (passive technique)
- ***High-Velocity:*** Velocity of a mortar varies from 300 m/sec to 100 m/sec
- ***Small:*** e.g. 81 mm mortar form factor restricts antenna size and distance

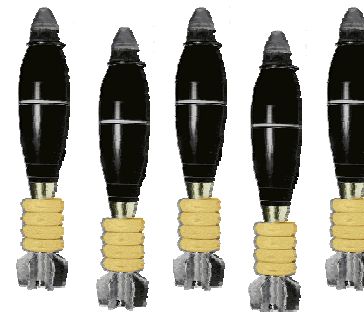
## Technology Enablers:

- Organic detection (cueing) capability
- Small, lightweight, wideband, and inexpensive RF receivers
- Inexpensive memory and processors
- Proliferation of guided weapons (IR, laser, GPS, etc.)

# DARPA RFGM Program

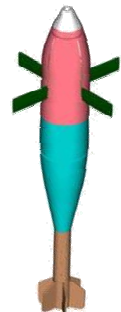
BAE SYSTEMS

- Replacement fuze/guidance package that effectively converts current, ballistic 81 mm mortar munitions into precision RF guided munitions
- Screw-on mod-kit
- Affordable, Easy to use
- Frequency range 30MHz to 3GHz
- Accuracy not dependent on visual observation
- Fire and Forget
- Passive, all-weather
- Technology that is scalable to other munitions



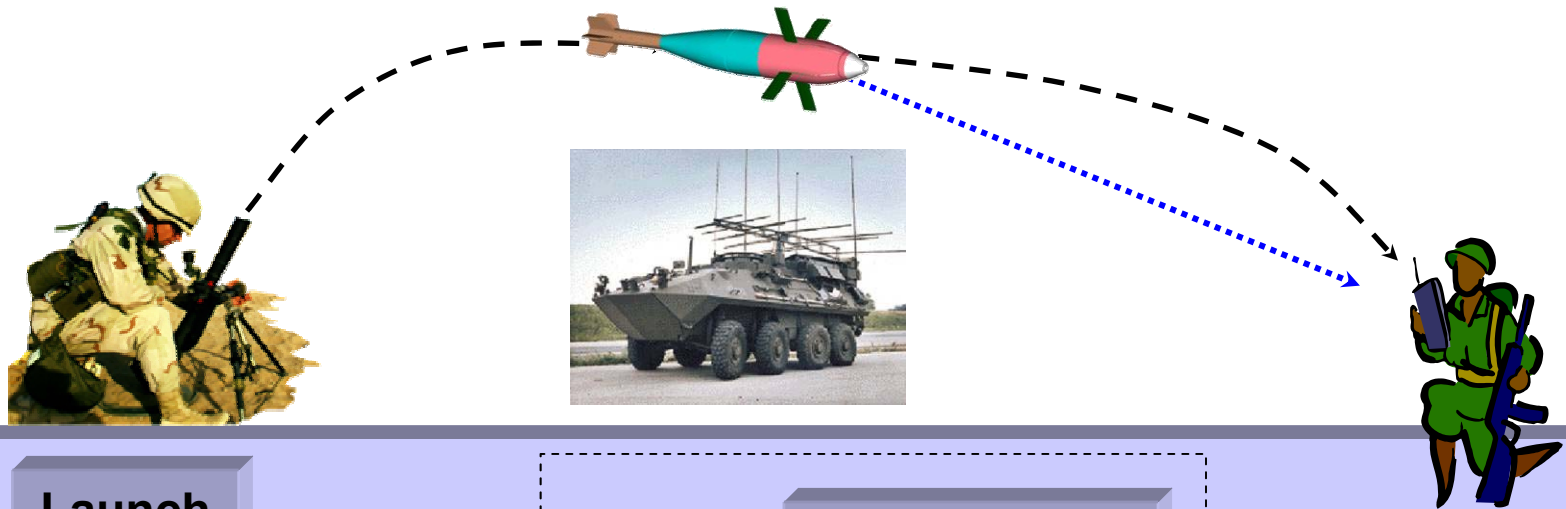
?

=



# System Operation

BAE SYSTEMS



Launch  
Cue

Geo-locate

Maneuver  
toward target

Detonation

Initial detection,  
discrimination, and  
Geo-location to  
<1.5km radius circle

<20m accuracy (CEP)  
with  $\ll 0.3\lambda$  aperture

Maneuver capability  
and stable control

3m Airburst  
using GOTS  
proximity fuze

## System Integration

- Miniaturize to a 81mm mortar round
- Cost effective
- Match maneuver, target, and munitions capability

Existing technology

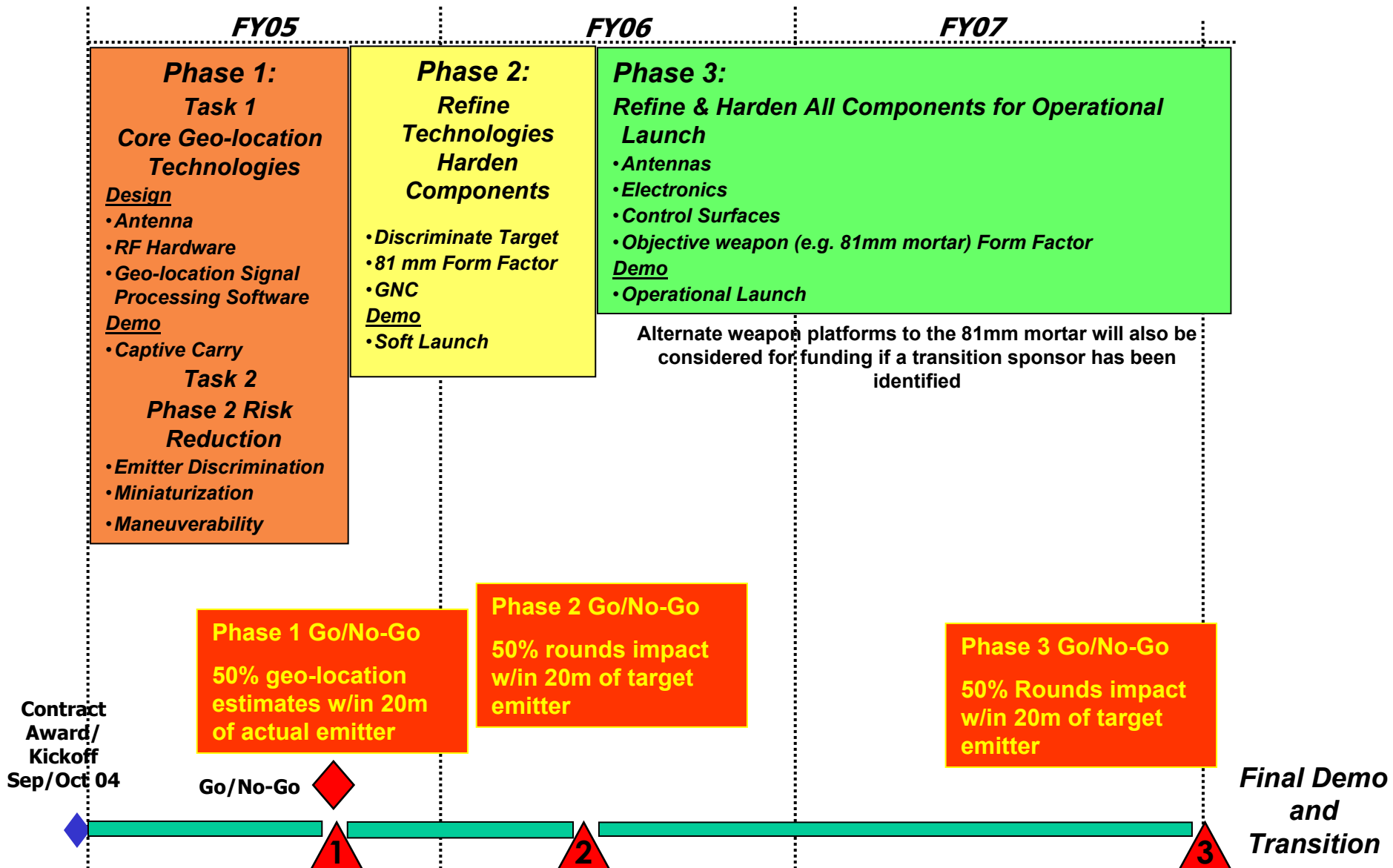
Extension of existing technology

Seedling analysis indicates feasible

- Cueing:
  - The weapon receives cueing information from an external system such as Wolfpack, ACS, etc.
    - Utilize SIGINT standard emitter descriptors (carrier frequency, bandwidth, modulation, etc.) to future proof weapon versus template matching emitter waveforms
- Geo-location
  - Despite high SNR condition, classic DF techniques alone will not work well enough due to the limited aperture size/spacing and the (low) frequency range of interest
- Maneuver toward target
  - Guidance/control techniques are well known (e.g. ERGM, PGMM, etc.)
- Detonation
  - Utilize existing GOTS fuze technology to avoid re-qualification costs
- System Integration
  - Optimizing the relationship between geo-location accuracy and aerodynamic control authority while minimizing weight, volume, and cost and impact on weapon range and effects
    - Integrating the RF Guided Munition kit with the fuze is preferred
    - Volume/length will need to be added to the weapon (mortar) for antennas, RF electronics, signal processing, and control surfaces in a manner that minimizes range loss
    - Using GPS is possible but an IMU may be sufficiently capable while being cheaper than SASSM modules – both add a precise targeting capability

# RF Guided Munitions Program

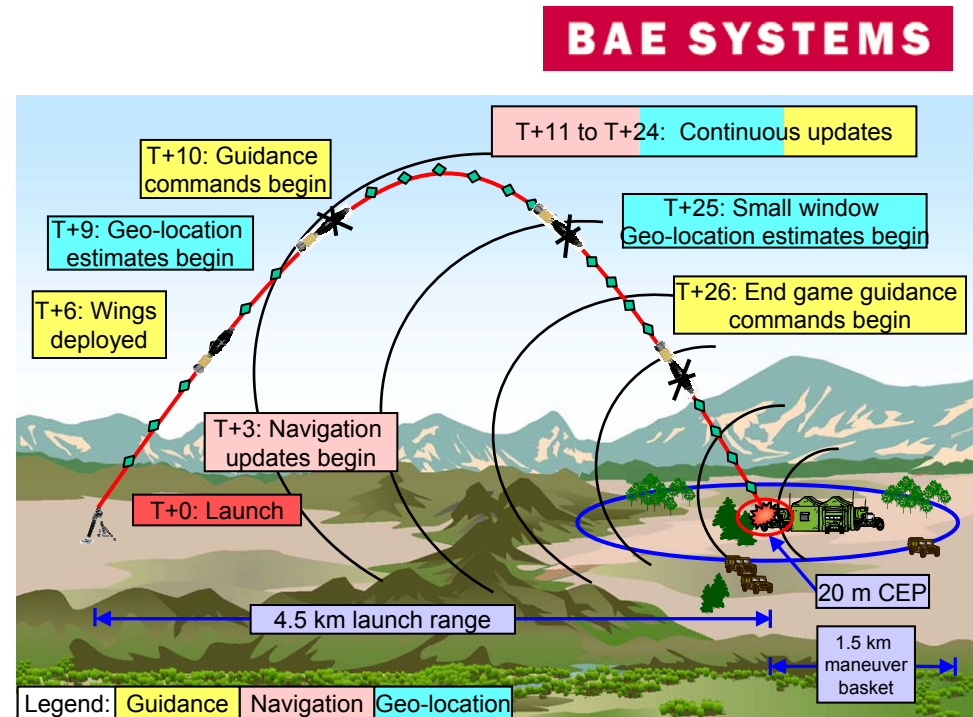
BAE SYSTEMS



# Geo-location Challenge

- **Geo-location Error Sources:**

- Thermal noise
- Quantization noise
- Phase noise
- Receiver spurs, intermods and harmonics
- Man-made noise and atmospheric noise at HF
- Navigation errors from position and roll sensors
- Channel mismatch errors
- Calibration errors
- Multi-path signal corruption
- Co-channel signal interference
- Platform motion induced modulation



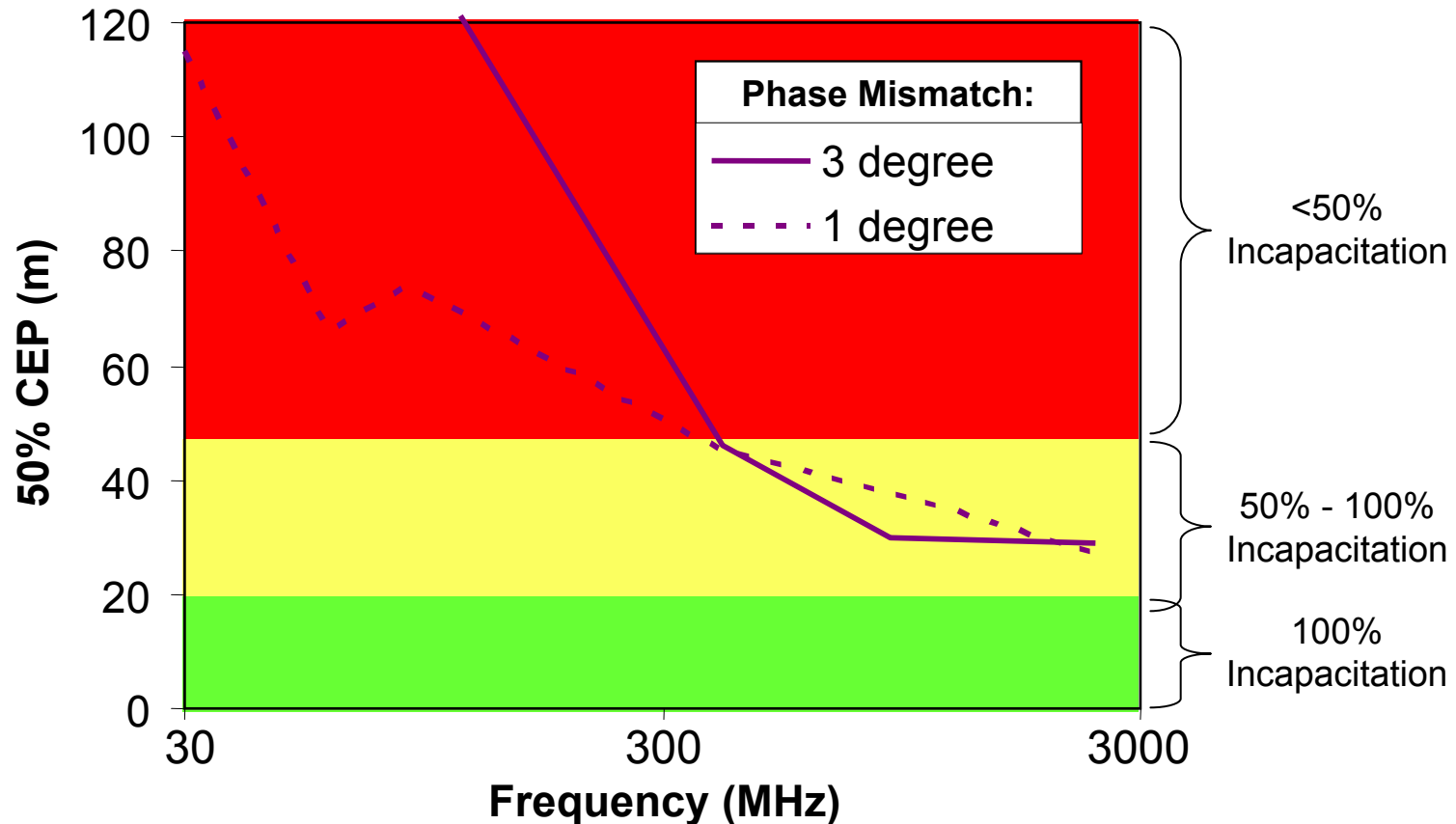
- **Geo-location Requirements:**

- Provide guidance commands well before apogee to support maneuver basket.
- Deal with multi-emitter environment. Guide to one emitter, not the centroid of emitters.
- Provide resiliency to multi-path and polarization.

# Geo-location Challenge

**BAE SYSTEMS**

Angular precision of classic DF techniques is limited by  $\lambda/D$ , SNR, and channel mismatch which is unacceptable for low frequency emitters



**Lower Frequency**

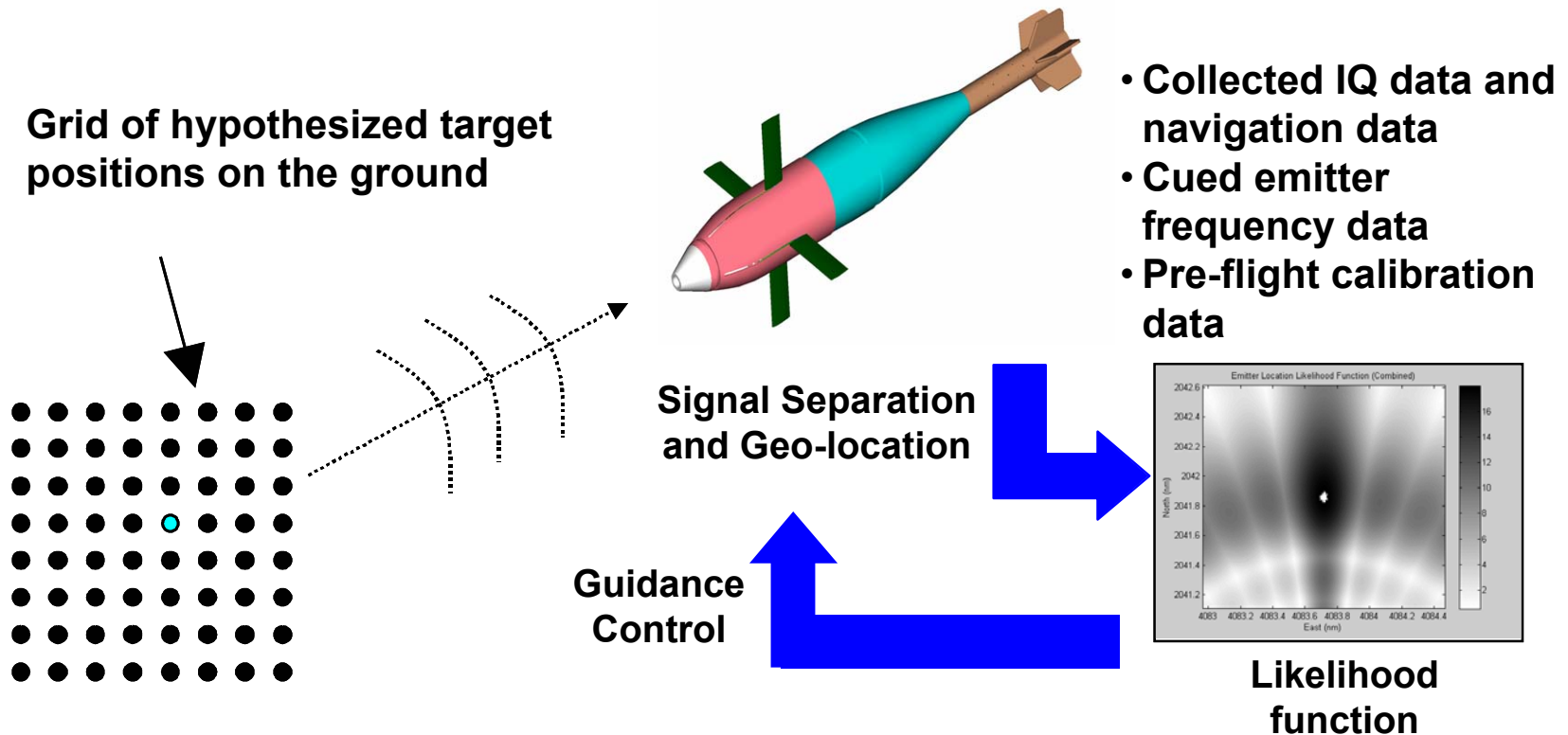
- Dominated by channel mismatch which causes a biasing error

**Higher Frequency**

- Dominated by imprecision in guidance (GPS/IMU error)

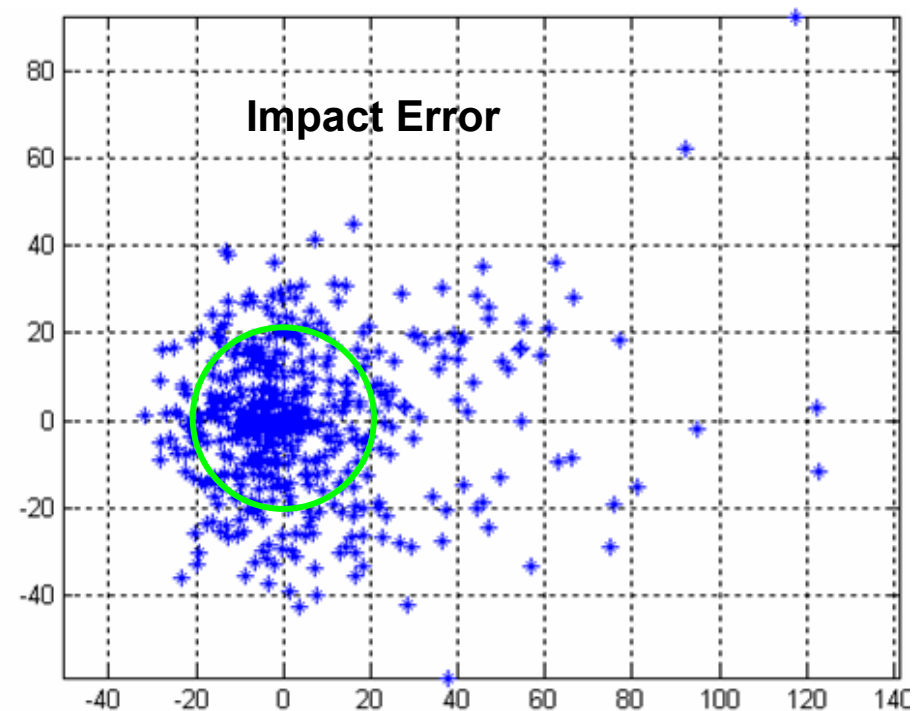
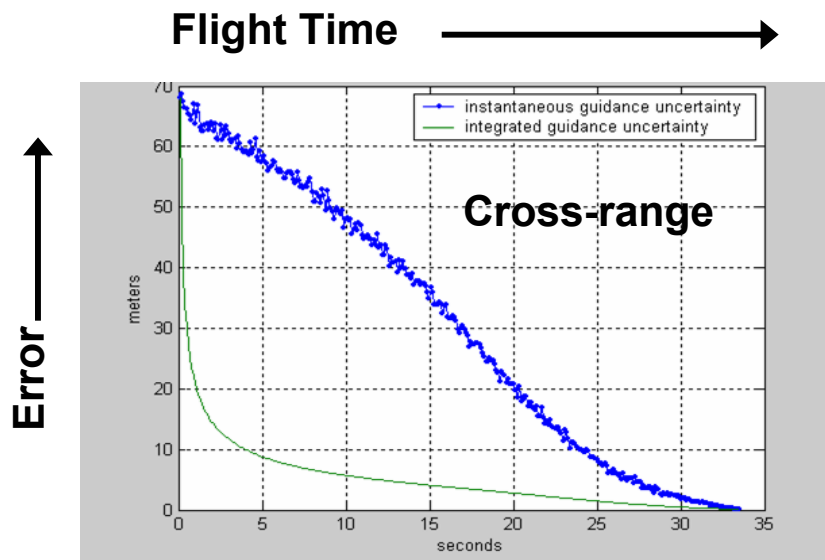
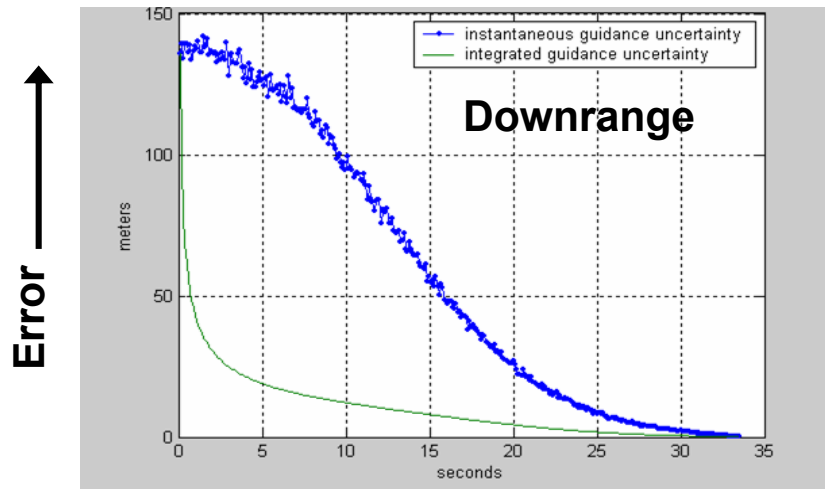
# Geo-location Processing

**BAE SYSTEMS**



**Geo-location method uses temporal, phase and amplitude information from all the antenna elements, separates signals of interest and then determines emitter geo-location metric by computing the probability likelihood surface of the potential emitter location as a function of its hypothesized location.**

# Geo-location and Guidance Performance



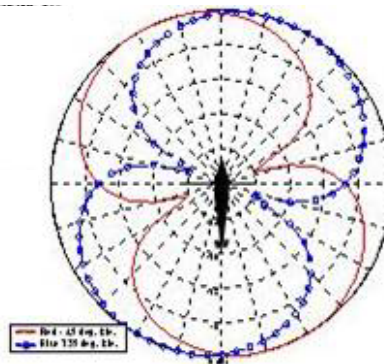
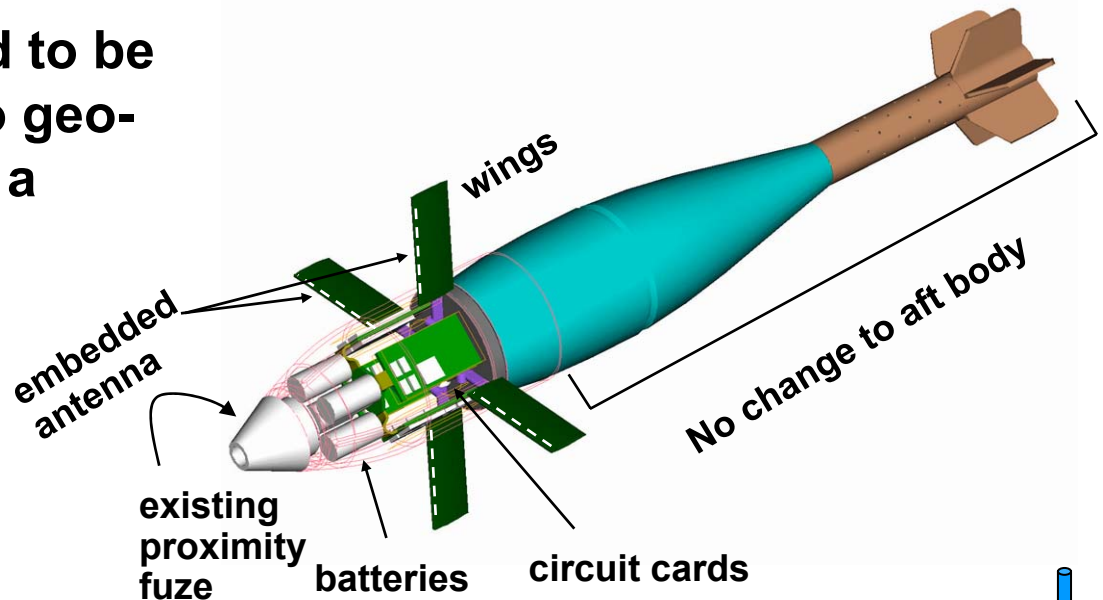
**Model of combined geo-location and guidance shows better performance than the specified 20m CEP goal with a maneuver basket of 1.5km in radius.**

# System Integration

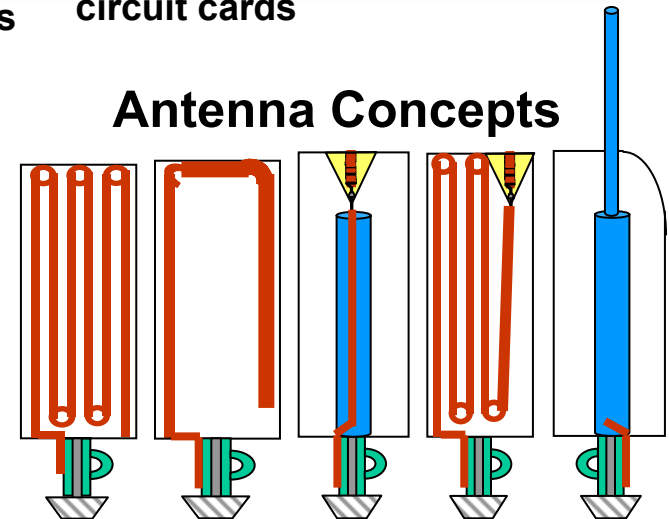
**BAE SYSTEMS**

Multiple subsystems need to be integrated, in addition to geo-location, to make RFGM a reality:

- Antennas
- Receivers
- Actuators
- Wings
- Navigation
- Guidance
- Control
- Signal Processing
- Power
- Cueing
- Fuze



## Antenna Concepts



# Questions?

# Points of Contact

**BAE SYSTEMS**

## **DARPA/ATO Program Manager**

**Dr. John Allen**

**jallen@darpa.mil**

## **BAE Systems Program Manager**

**Ms. Marianne Tenore**

**marianne.tenore@baesystems.com**

**Phone: 603-885-8470**

## **BAE Systems Management**

**Dr. Cory Myers**

**cory.s.myers@baesystems.com**

**Phone: 603-885-6845**

## **BAE Systems Business**


**Development**

**Mr. Daniel Bradford**

**daniel.bradford@baesystems.com**

**Phone: 603-885-5937**

Approved for Public Release, Distribution Unlimited, Reviewed by ATEC PAO (April 2005)



# ***ATEC UPDATE TO NDIA***

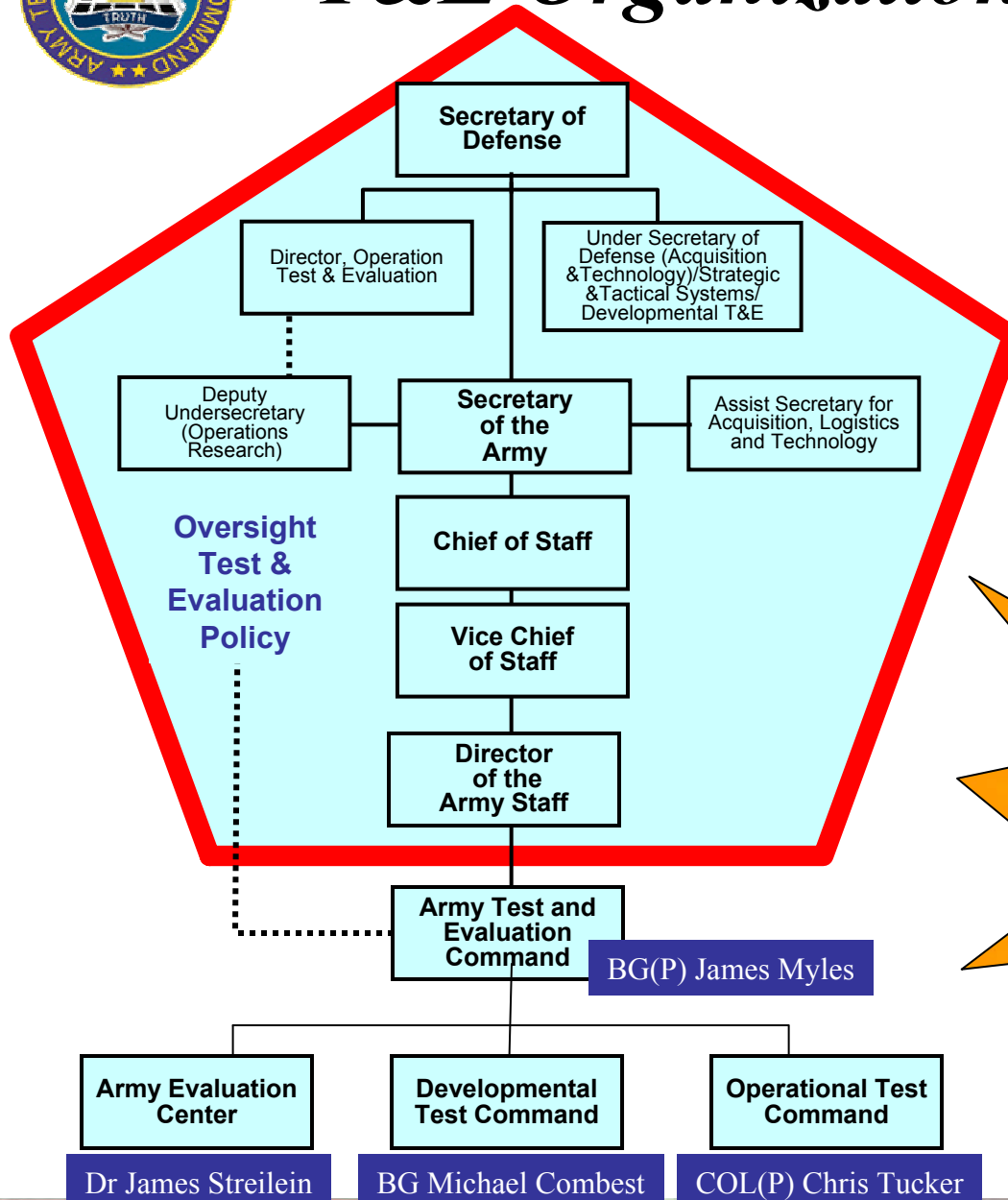
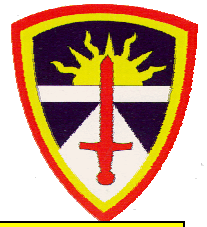
***27 April 2005***

***Presented by:***

***BG(P) James R. Myles***



# T&E Organizational Structure

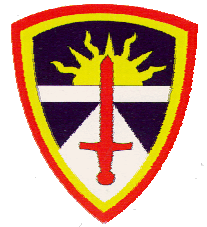


**Mission:** ATEC plans, conducts and integrates developmental testing, independent operational testing, independent evaluations, assessments and experiments *in order to provide essential information to decision makers*

**Required by  
OMB & OSD  
to be  
Independent**

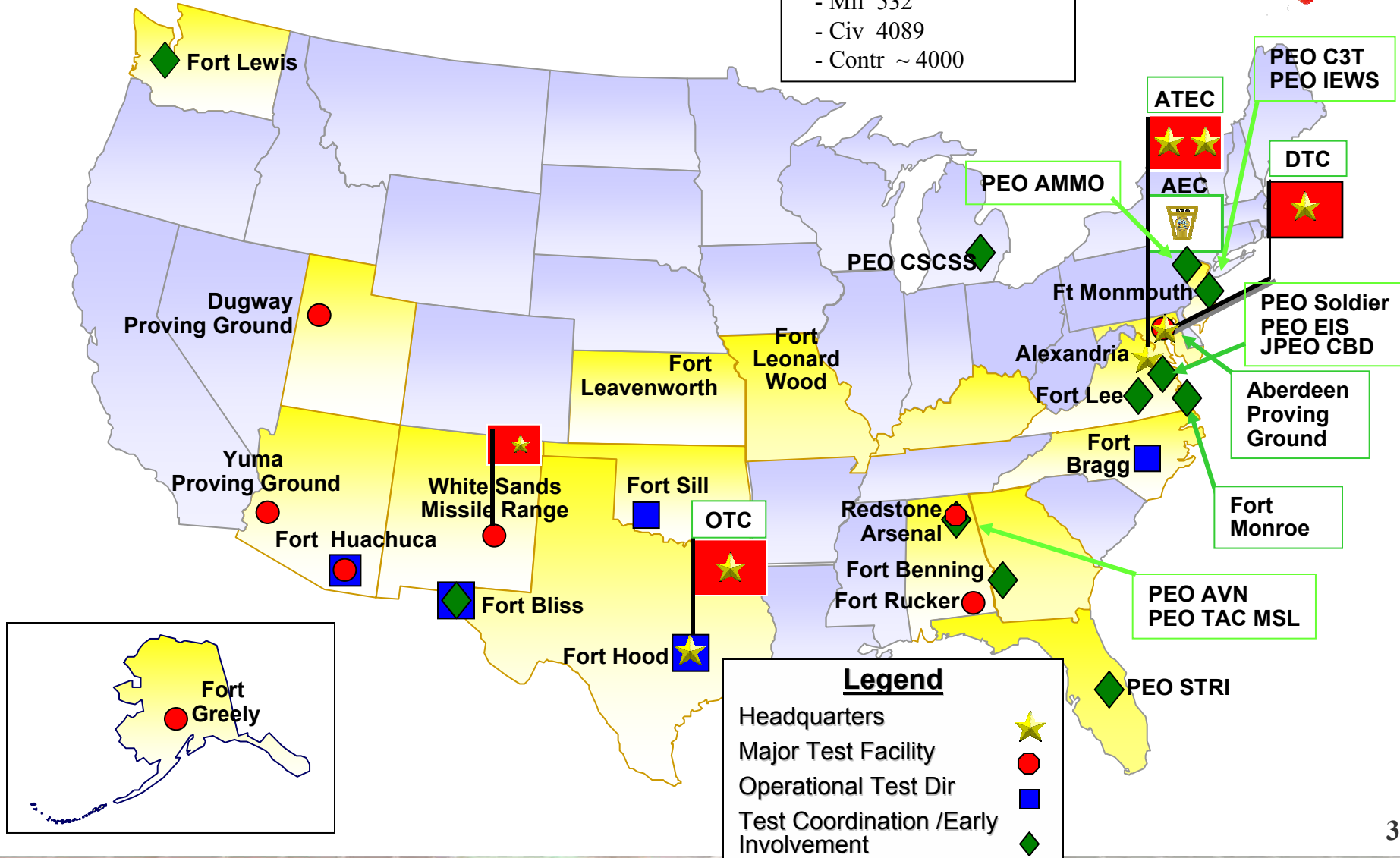


# Where We Are



Total Strength ~ 8621

- Mil 532
- Civ 4089
- Contr ~ 4000





# *The Army's T&E is Unique*



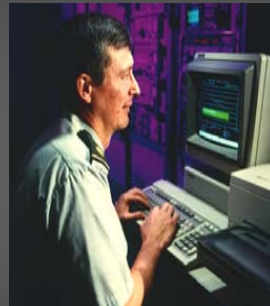
## ATEC

### DTC



**Developmental Testing**  
*engineering type tests conducted  
under controlled conditions*

### AEC



**Evaluation**  
*independent assessment of all  
testing and simulation*

### OTC



**Operational Testing**  
*testing conducted using real  
soldiers in simulated combat*

***ATEC integrates  
developmental and  
operational testing***



# *ATEC T&E Philosophy*

- Testing is part of acquisition process
- Two Fundamental Missions
  - Make system better (test-fix-test)
  - Provide Info to Decision Makers
- Does it Work...How do I know?
- Evaluation in Depth:
  - Platform → System of Systems → Unit Mission
- No Pass/Fail → Capabilities and Limitations



**Good Enough ≠ Anything will do**



# *Where are we headed*



- OTs with fewer troops—  
tougher and shorter
- Rapid Acquisition: Spiral  
Development, DT/OTs,...
- System of systems T&E
- Support to War is the norm
- OTs During Major Training  
Events (NTC, JRTC,...)





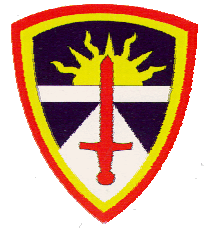
# ***GWOT -- What is ATEC Doing About It***



- War Support
  - Early Involvement with PMs & REF
  - Focus on performance in the AOR
  - Soldiers in DT / Limited User Testing
  - Respond to Warfighter!
    - Up-Armor Vehicles, Slat Armor, Stryker, ECMD, Robotics,..
  - Deploy ATEC Assessment Team in Theater
- Safety Confirmations
- Capabilities and Limitations Report
  - For the Commander
  - What do we know (Cap and Limits)
  - What don't we know
  - Safety, C/L, Training, Supportability and Accountability



# *Back-up Slides*



# Additional Thoughts

- **NOT YOUR DAD'S ATEC**
  - LIKE THE ARMY, ATEC STANCE AND BALANCE HAS CHANGED
  - FOCUS IS GWOT AND SOLDIERS IN HARMS WAY TODAY
  - TIMELINES HAVE SHRUNK TO SUPPORT RAPID ACQUISITION...STANDARDS HAVE NOT!
  - DATA VOIDS ARE FILLED WITH OUR EXPERIENCE AND BEST MILITARY JUDGEMENT
- **WE TEST-FIX-TEST AND PROVIDE INFO TO OUR SENIOR LEADERS TO MAKE DECISIONS**
- **WE ARE NOT SEPARATE FROM THE ACQUISITION COMMUNITY**
- **GET US INVOLVED EARLY**
- **WE DO DT/OT**
  - UNDERSTAND THE SUBTLETIES...WILL LOOK AT SOMETHING BEFORE IT IS READY...WE KNOW THE DIFFERENCE.
  - BECAUSE WE SEE THAT IT WORKS IN DT DOESN'T MEAN IT WORKS WITH SOLDI
- **LOGISTICS, TRAINING, ACCOUNTABILITY OF THE SYSTEMS ARE SHOWSTOPPERS FOR OUR SOLDIERS.**
  - LACK OF TRAINING AND LOGISTICS PROVIDES BAD REPUTATION FOR THE SYSTEM...HARD TO REMOVE THE STIGMA
- **NDAA 03**
- **PUT THE SOLDIER FIRST AND YOU ARE NEVER WRONG**
- **MOMS AND DADS OF AMERICA HAVE EXPECTATIONS**
  - THAT THEIR SON AND DAUGHTER RETURN HOME TO THEIR FAMILY
  - THAT THEIR SOLDIER HAS THE BEST EQUIPMENT ON THE FACE OF THIS EARTH
  - AND, THAT WHEN NEEDED, IT WILL WORK...THAT IT WILL WORK

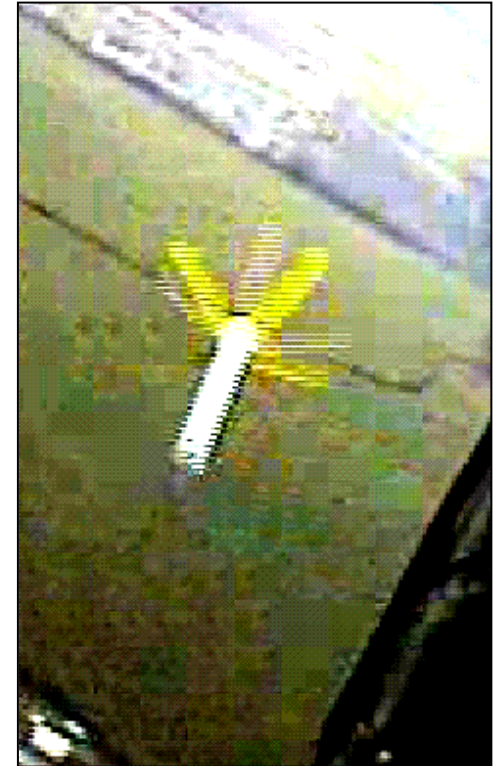
# Modeling Efforts for Autorotation Delivery System Concept Development

Presented  
at the  
40th Annual Guns & Ammunition/  
Missiles & Rockets  
Symposium & Exhibition

April 25-28, 2005 New Orleans, LA

*David C. Rutledge, Ph.D., Staff Engineer, United Defense, L.P.*

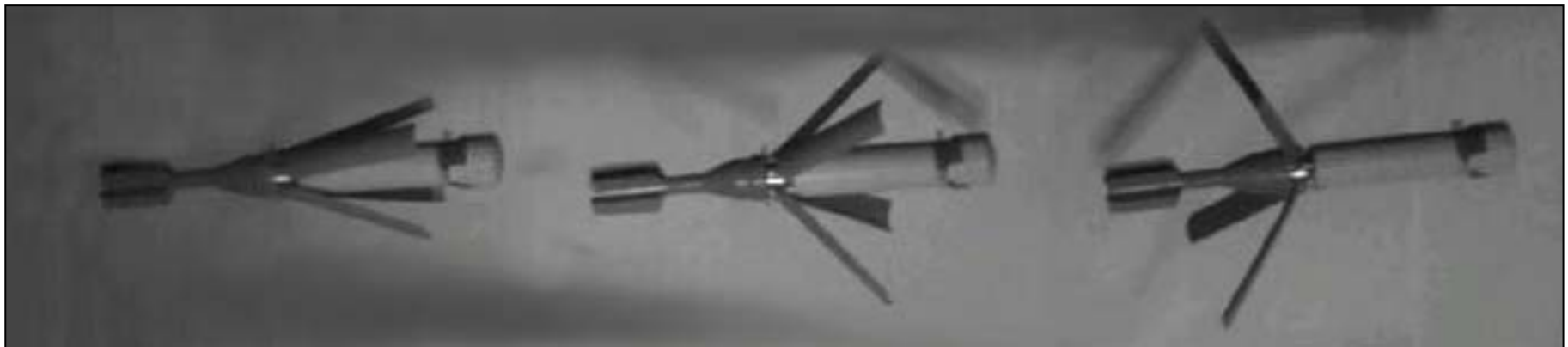
*Mark Costello, Ph.D., Oregon State University*



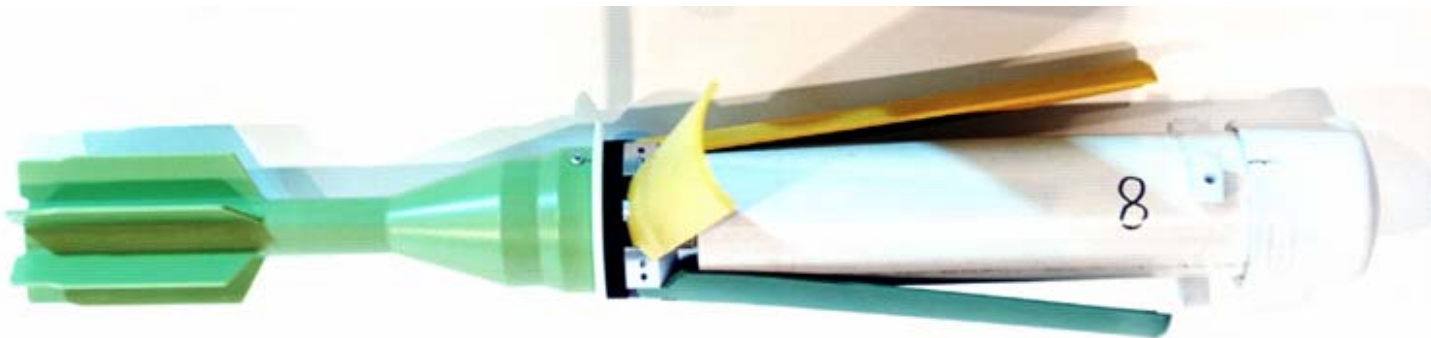
***\* Autorotation Delivery Systems is patent pending***

# Presentation

- Overview
- Deployment Sequence
- Applications
- Modeling Performed
- Axisymmetric Model
- BOOM Model
- Summary and Video



- ❑ The Autorotation Delivery System, formerly known as Projectile Kinetic Energy Reduction System (PKERS), is a concept developed by United Defense as an autorotation decelerator for high-value tactical payloads
- ❑ Combines a projectile body with a deployable rotor that reduces descent velocity via autorotation
- ❑ Modeling and simulation will facilitate the optimal design process during each stage of development



# Deployment Sequence

- ❑ Rotors stowed conformal to the sides of projectile body prior to deployment
- ❑ During deployment, rotors rapidly rotate outward due to projectile spin and aerodynamic drag
- ❑ Transition to autorotation occurs as the rotor blades become aerodynamically loaded coupled with an increasing spin rate
- ❑ System attains a steady descent velocity when the inertial and aerodynamic forces reach equilibrium



# Applications

- ❑ United Defense is developing the Autorotation Delivery System as an alternative to conventional parachutes for certain applications
- ❑ Flight characteristics and descent velocities are tailorable for different missions and payloads (*e.g., land and sea sensors, cargo, battle damage assessment, munitions*)
- ❑ Can be gun launched, mortar launched, or air dropped
- ❑ Modular design allows accommodation of all the necessary components required for precision guidance



**First Generation Autorotation  
Delivery System integrated with  
Talley SMAW-D Motor**

# Modeling Performed

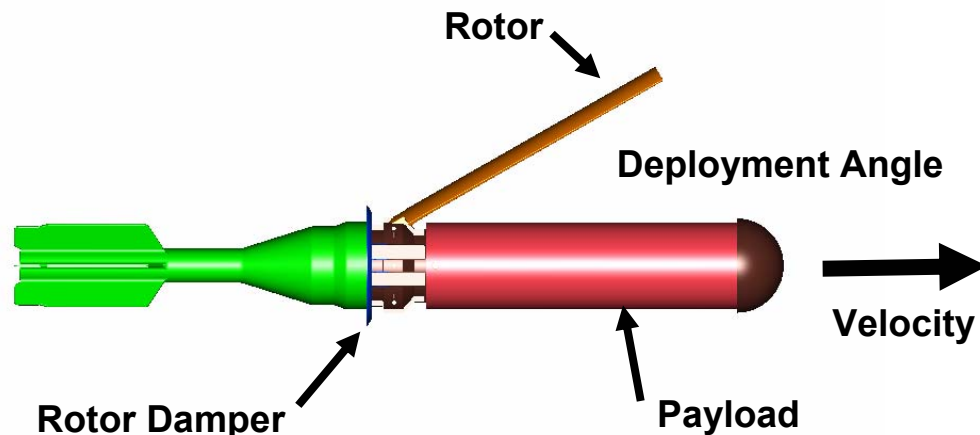
- An axisymmetric spreadsheet-based model was developed to estimate the dynamics and loads as the rotors initially open and impact the damper
- A detailed flight mechanics model was developed and integrated into the BOOM smart weapon simulation system to model the flight dynamics from initial rotor deployment to full autorotation

# Axisymmetric Model:

## Initial Deployment

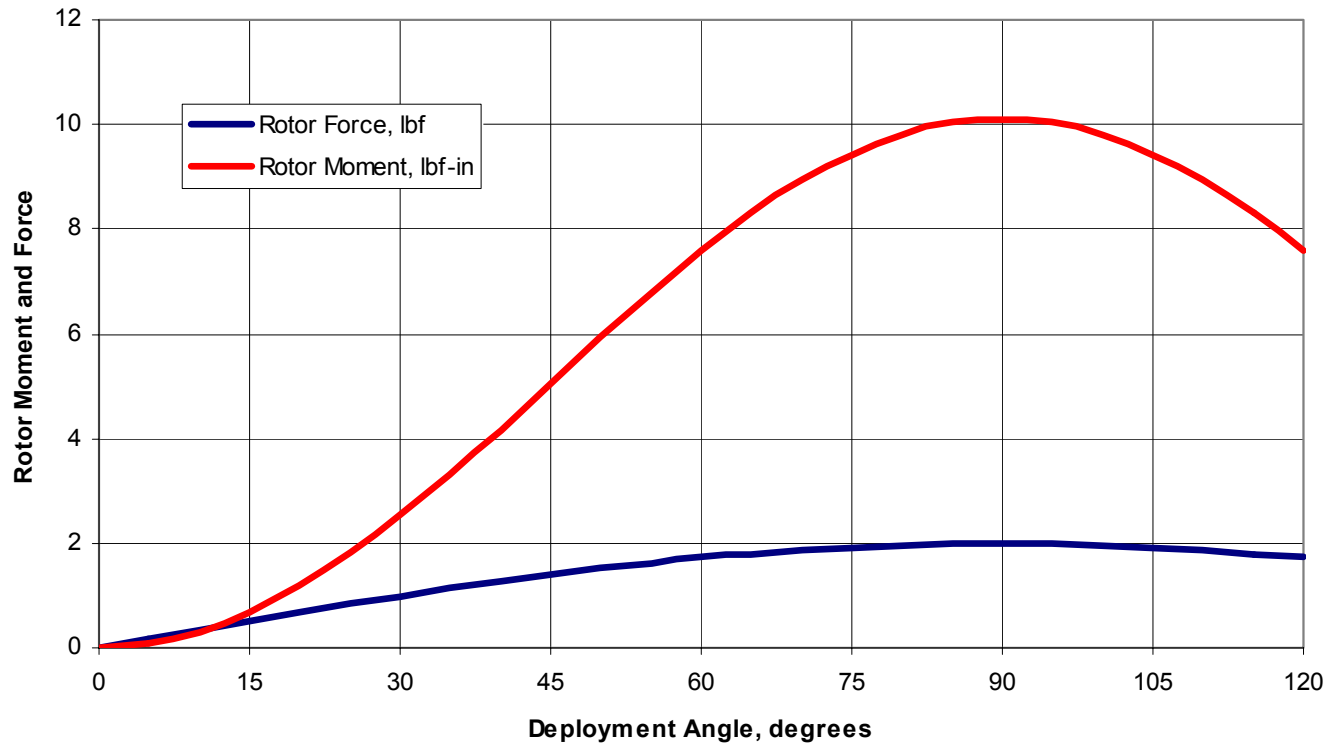
- The Axisymmetric Model is a quasistatic spreadsheet-based concept development tool
  - Allows estimates of system performance and parametric studies
  - Assumes symmetry about the longitudinal spin axis, zero spin rate, and conservation of rotor angular momentum
  - Provides 2 Degrees of Freedom (DOF) for the projectile body (forward velocity and spin) and 1 DOF for each rotor blade (deployment angle)

- Axisymmetric model assumptions:
  - Centrifugal loads due to flight element spin are a minor contributor during initial rotor opening (zero spin assumed)
  - Flight element velocity constant during initial deployment (worst case)
  - Aerodynamic drag is then a function of deployment angle
- Calculate upper limit on rotor force and moment about rotor hinge as a function of deployment angle



# Aerodynamic Loads on Rotor

Rotor Force and Moment at 100 fps Deployment Velocity

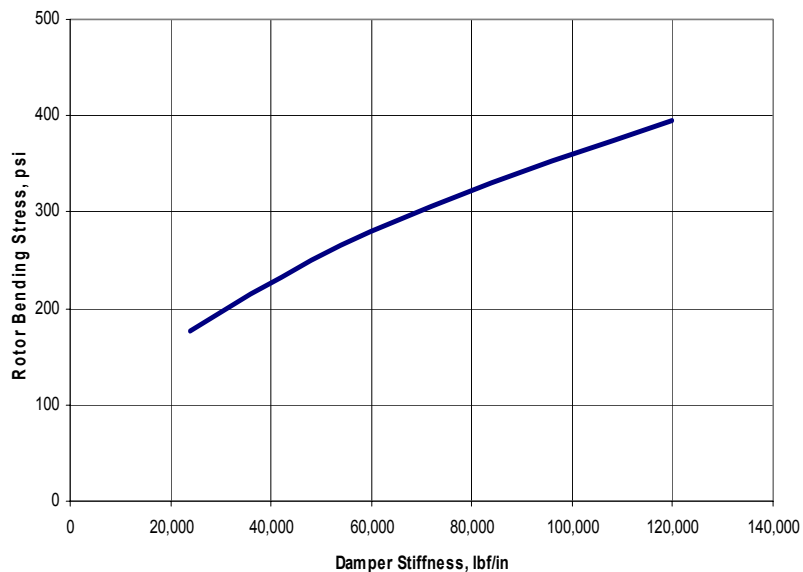


# Calculation of Damper Force

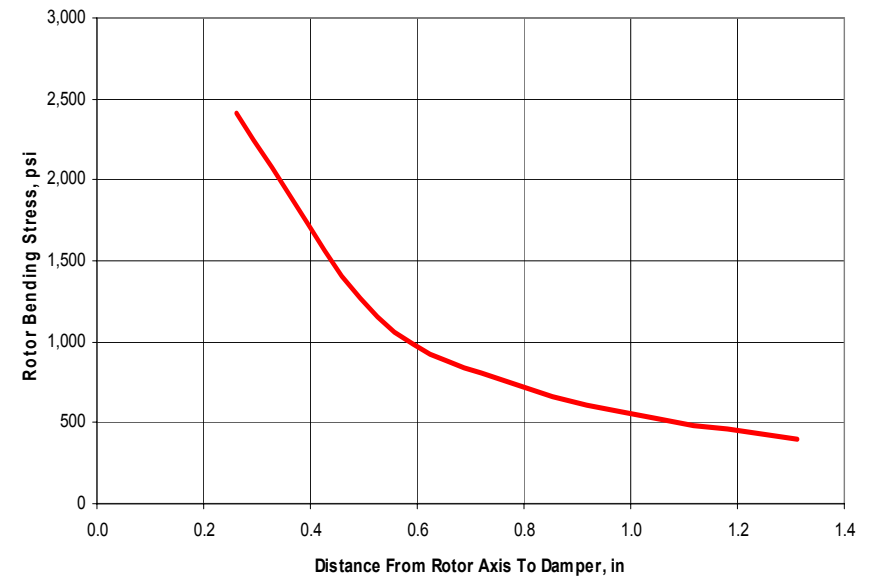
- ❑ Worst case rotor loads accelerate the rotor open until they impact the damper at approximately 120 degrees
- ❑ Opening moment is numerically integrated versus deployment angle to get the angular momentum at initial impact with damper
- ❑ Corresponding kinetic energy is absorbed by the damper
- ❑ Maximum damper force is calculated for multiple damper locations, shapes, and materials to optimize design

# Rotor Bending Stress Results

Rotor Bending Stress at 100 fps Deployment Velocity



Rotor Bending Stress at 100 fps Deployment Velocity



**Worst case force is used to design rotors so they can safely survive the bending stress during initial deployment**

# Rotor Deployment Video

United Defense

**Camera 2:**  
0 – 12'



**Camera 3:**  
12 – 24'



**Camera 4:**  
24 – 36'



# BOOM Model:

## Detailed Flight Dynamics

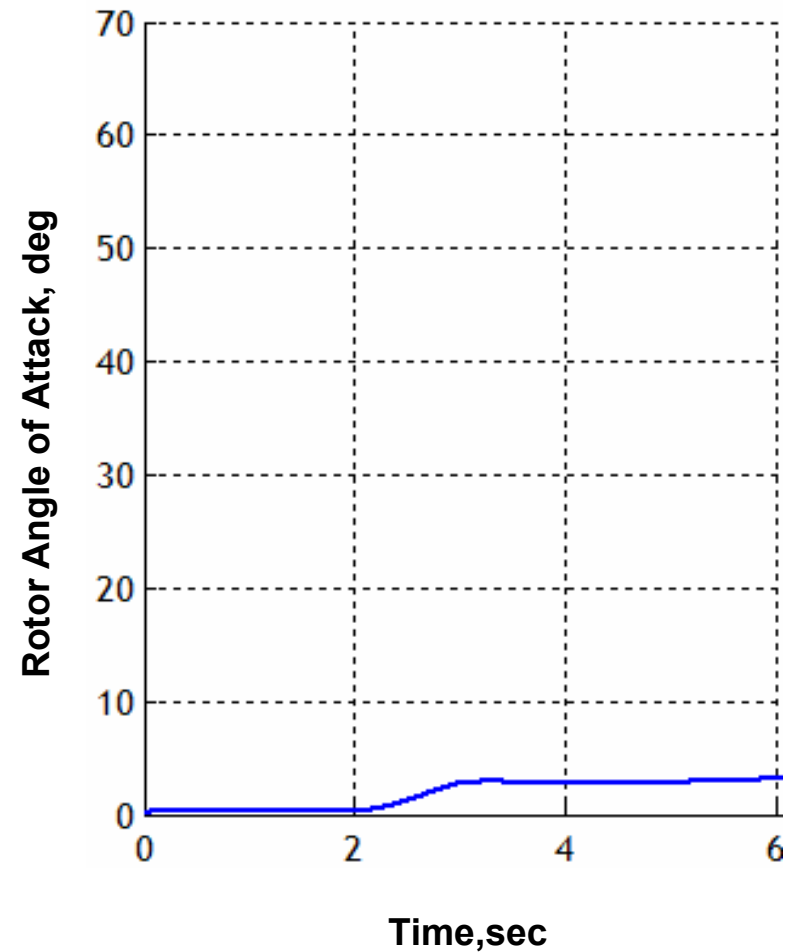
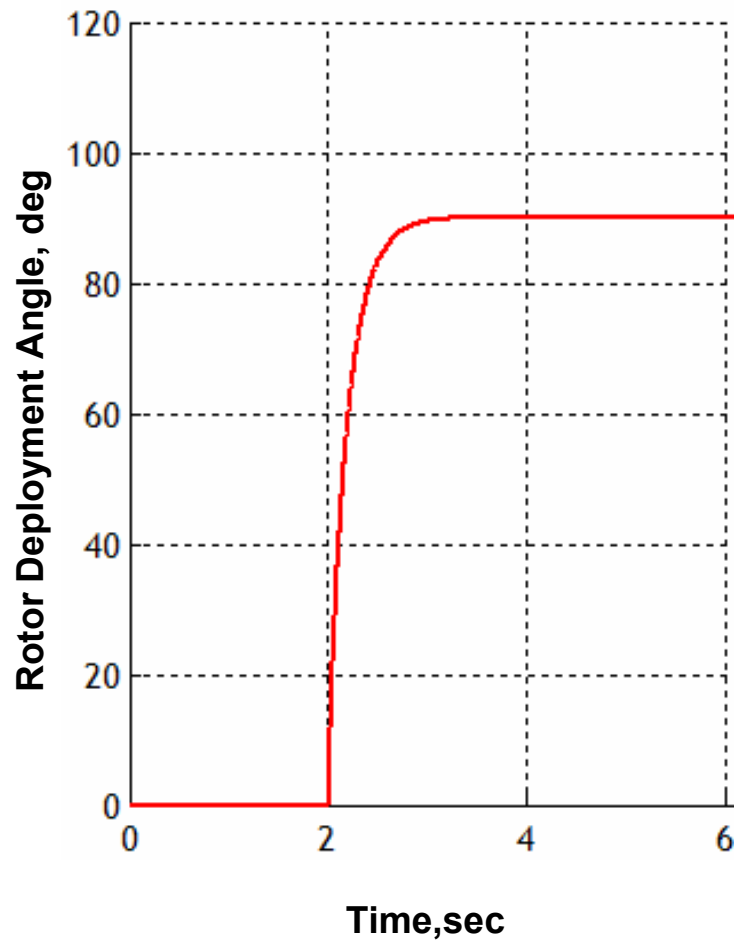
- The BOOM model is a detailed design and development tool
  - BOOM is a smart weapon simulation system
  - Full model of the delivery system flight mechanics was developed and integrated into BOOM
  - Provides 6 rigid-body DOF for the projectile body (flight element center of gravity position and orientation angles), 1 DOF for each rotor blade (deployment angle), and a 3-state rotor dynamic inflow representation

# BOOM Model Description

- Aerodynamic loads on the projectile body are a function of angle of attack and Mach number
- Aerodynamic forces and moments on the rotors are computed using blade element theory; airfoil lift and drag coefficients are a function of local rotor section angle of attack and Mach number
- BOOM simulations then provide the dynamics of the system as a function of time
- The simulation presented here has the following initial conditions:
  - Linear velocity 43 m/s (141ft/s)
  - Spin (Roll) rate 20 rad/s (3.2 rev/s)
  - Deployment angle fixed at 90 degrees

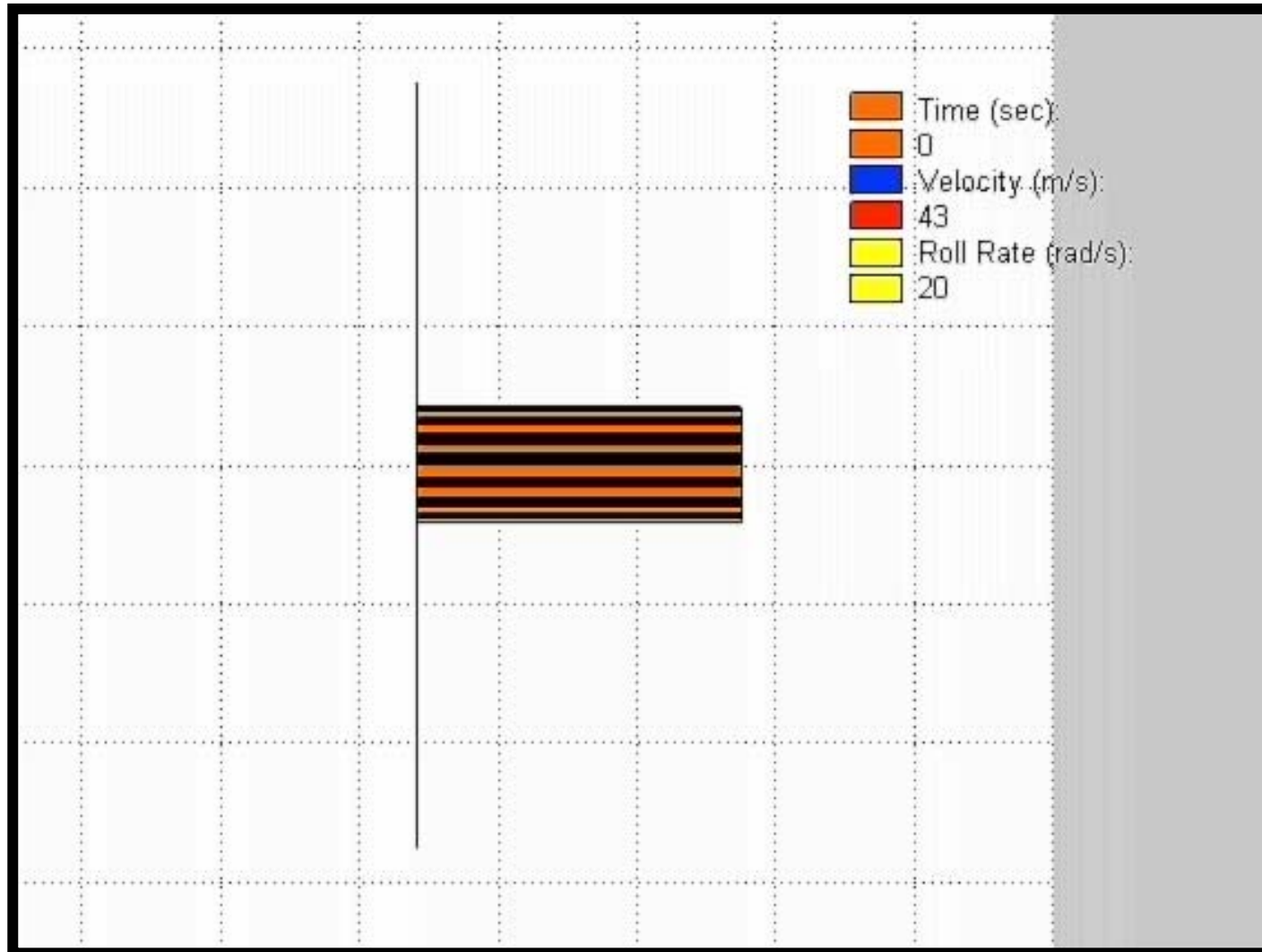
# BOOM Model Rotor Kinematics

United Defense



# BOOM Model Top View Animation

United Defense



- ❑ BOOM model results indicate that the concept will deploy in a manner consistent with flight tests
- ❑ Model has not been validated yet. Validation with test data is planned for the future, making the model capable of supporting future design, flight control system development, and payload integration
- ❑ This simulation assumes that all rotors have the same deployment angle at any time; this causes a short numerical instability that's not present in the actual system
- ❑ Model to be modified to allow each rotor to have different deployment angles

# Summary and Video

United Defense

- Test configurations have proven to be robust enough to survive deployment stresses
- Additional development, testing, and demonstration is planned to validate the 6-DOF model and applications
- Exploring a variety of Payloads and Applications
  - Sensors, Cameras, Munitions
  - Reconnaissance, Surveillance, Repeaters



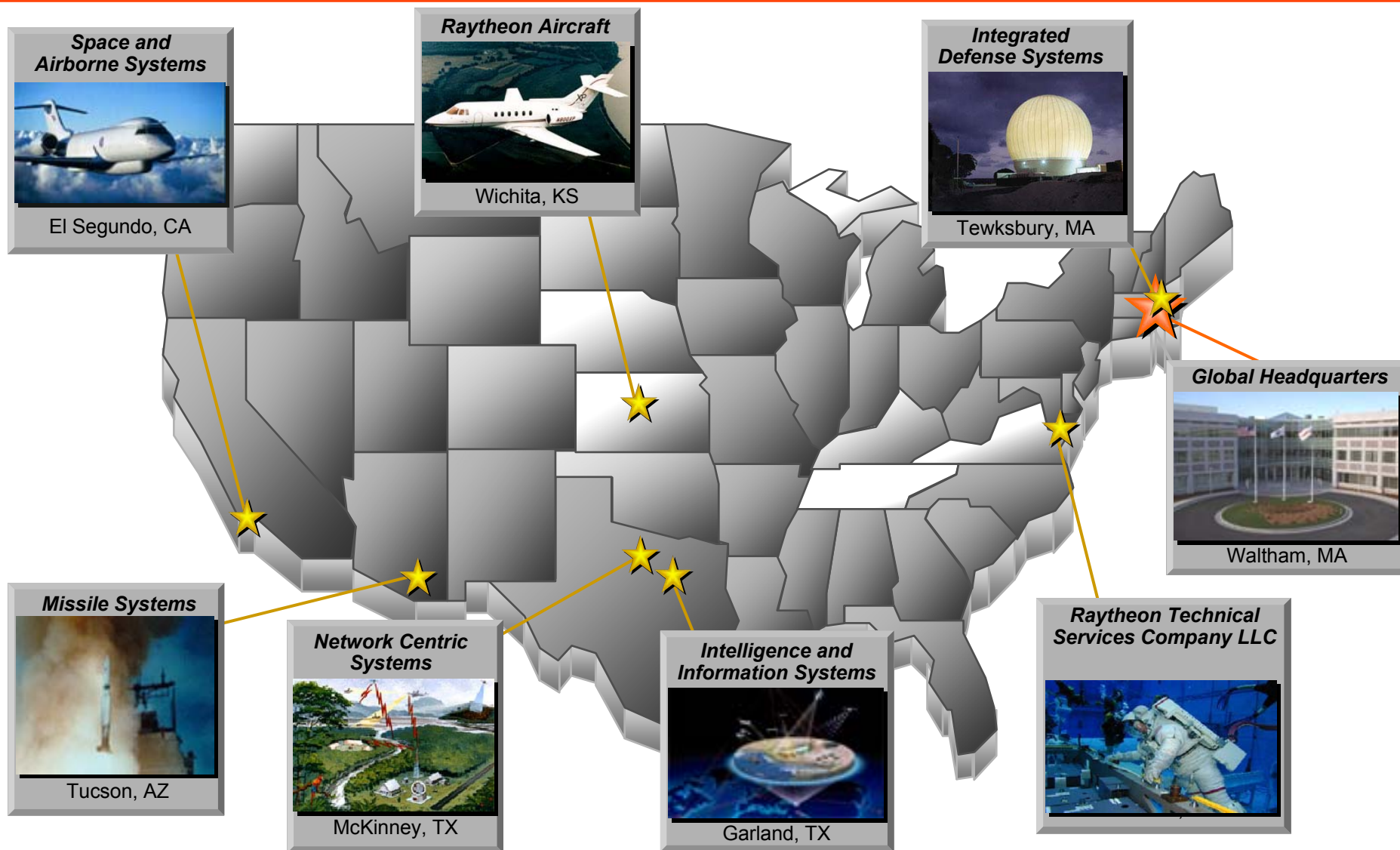
# Raytheon Missile Systems: A Global Perspective

**Robert D. Salyer**  
Director, Business Development  
Raytheon Missile Systems

**NDIA Symposium**  
**April 27, 2005**

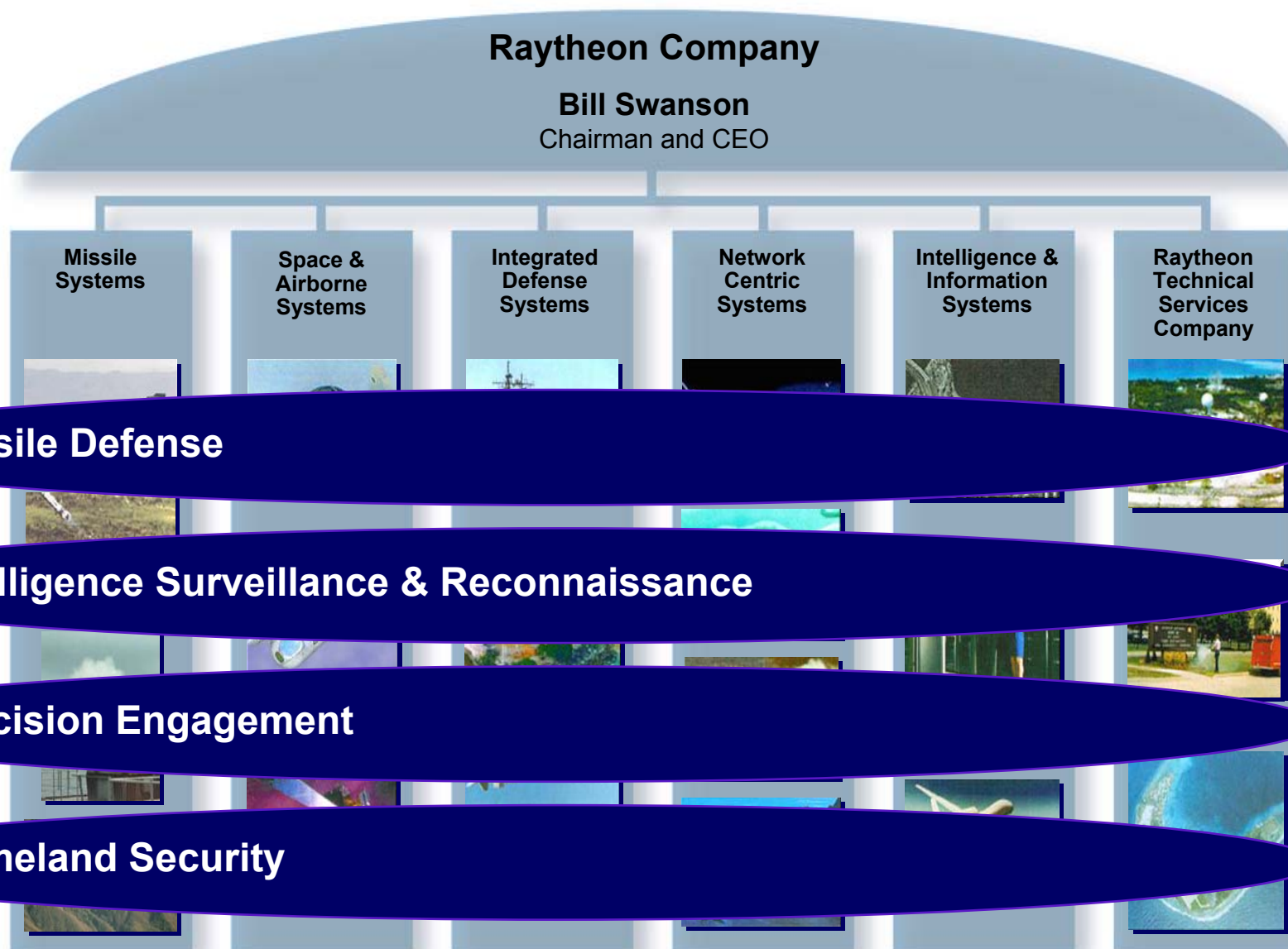


# Raytheon Company



**80,000 Employees; 2004 Revenue: \$20.2B**

# Business / SBA Intersection



# Customer-Focused Marketing



- Meet our commitments
- Actively seek every opportunity to proactively work with our customers to define their needs
- Develop and provide the best solutions
- Earn the customer's confidence

**Customer Must View Us As a Valued “Partner of Choice”**

# Raytheon Missile Systems – Who We Are

- 2004 sales: \$3.8 billion
- 11,000 employees
- Headquartered in Tucson, Arizona
- World's largest developer, producer and integrator of weapon systems
  - More than 1 million missiles produced since 1954
  - 70% domestic; 30% international
- Broad weapons portfolio
  - Missiles
  - Smart munitions
  - Projectiles
  - Kinetic intercept vehicle
  - Directed energy weapons
- Customers: all U.S. military services; Allied Forces of more than 40 countries



# **Our Vision**

*Effective*

*Affordable*

*Quick*

*Worldwide*



# Missile Systems



Air-to-Air	Strike	Land Combat	Naval Weapon Systems	EKV	Advanced Missile Defense & Directed Energy Weapons	Kinetic Energy Interceptor	Advanced Programs
AIM-9X	ACM	Javelin	ESSM	EKV	DST	Kinetic Energy Interceptor	AT3
AMRAAM	HARM	Stinger	Phalanx 1B		Advanced KV Technology		Silent Eyes™
ASRAAM	JSOW	TOW	RAM		NFIRE		UAVs
HARM Targeting System	Maverick	NLOS-LS	STANDARD Missile-2 (Block IIIA / IIIB / IV)		HEL		Loitering Weapons
Sidewinder	Paveway™	Excalibur (XM982)	SeaRAM		HPM		Long Endurance Vehicles
AMRAAM P <sup>3</sup> I Phase 3/4	Tomahawk		SM-3		Navy HELWS		Advanced Cruise Missiles
	MALD		SM-6				
	Precision Guided Bomb		Sparrow				
	Tactical Tomahawk		ERGM				

# Comparative Defense Budgets -- 2005

- US: \$401B
- Germany: \$31B
- UK: \$53B
- Australia: \$13B
- Japan: \$46B
- South Korea: \$20B

Note: All Budget Figures above in \$US



# How Defense Sells Into International Market

- Foreign Military Sales
- Direct Commercial Sales
- International Traffic in Arms Regulations
- Congressional notification



**Highly Regulated Industry**

# International Challenges

- Buy European/Buy America
- Lack of integration into U.S. markets
- Technology transfer
- Offsets – desire for “noble” work
- Fluctuating exchange rates



**International Marketplace Complex, Unpredictable**

# Enablers

- **Desire for U.S. products/technology**
- **Workshare opportunities**
- **Innovative contract structures**
- **Co-development opportunities**
- **Economies of scale reduce cost of U.S. production**



**Win-win Solutions Attractive to Buyers**

# Industry Response

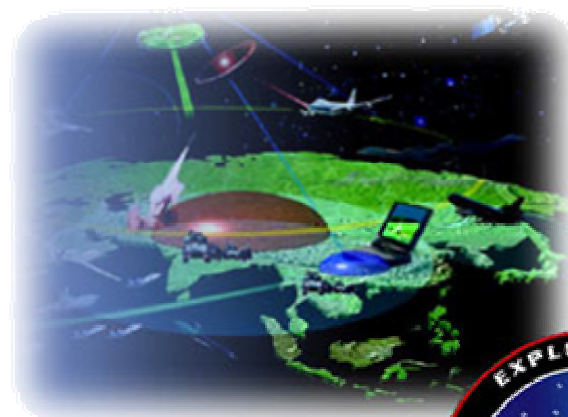
- **Grow international presence**
  - Raytheon International Inc.
  - Regional in-country expertise
  - Business development/program teams on the road
  - Visibility at international trade shows/events
- **Joint ventures**
  - Diehl Raytheon Missile Systeme
  - Thales Raytheon
- **Joint development opportunities**
  - ESSM
  - Excalibur
  - RAM
- **Co-production agreements**



**Relationships are Key**

# Looking into the Future

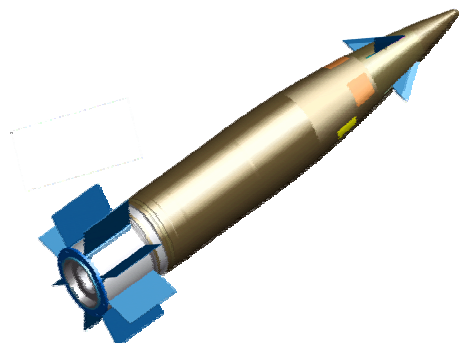
- Future “netted” battlespace
  - “Missile as a Node in the Net”
- Expanding into new markets
  - Directed energy
  - NASA space exploration
  - Guided Projectiles
  - Total life cycle logistics support
- Requires system engineers/  
system architects









**Expanding the Core Beyond the Missile Market**

# RMS Guided Projectile Family

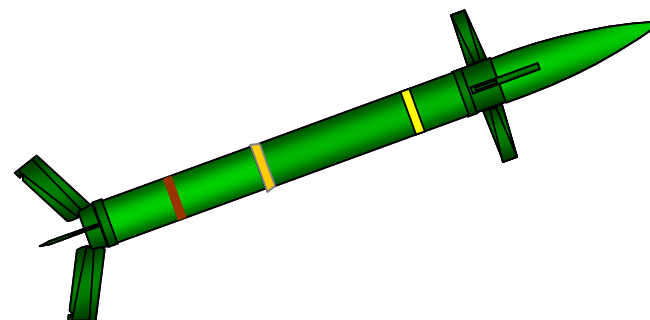
## Excalibur









### Mission

-  Indirect fires for legacy, interim and objective force
-  Paladin, XM777 and NLOS Cannon
-  Extended range munition
  -  39 Cal >37 Km
  -  52 Cal > 47 Km
-  Precision guided, <20m CEP

## Extended Range Guided Munition



### Mission

-  Naval Surface Fire Support
-  DDG81 MK45 MOD4 (5") Gun
  -  Cruiser Conversion
-  Extended Range Munition
  -  >41 Nmi
-  Precision Guided, <20m CEP

# Phalanx Overview

## **Primary Mission:**

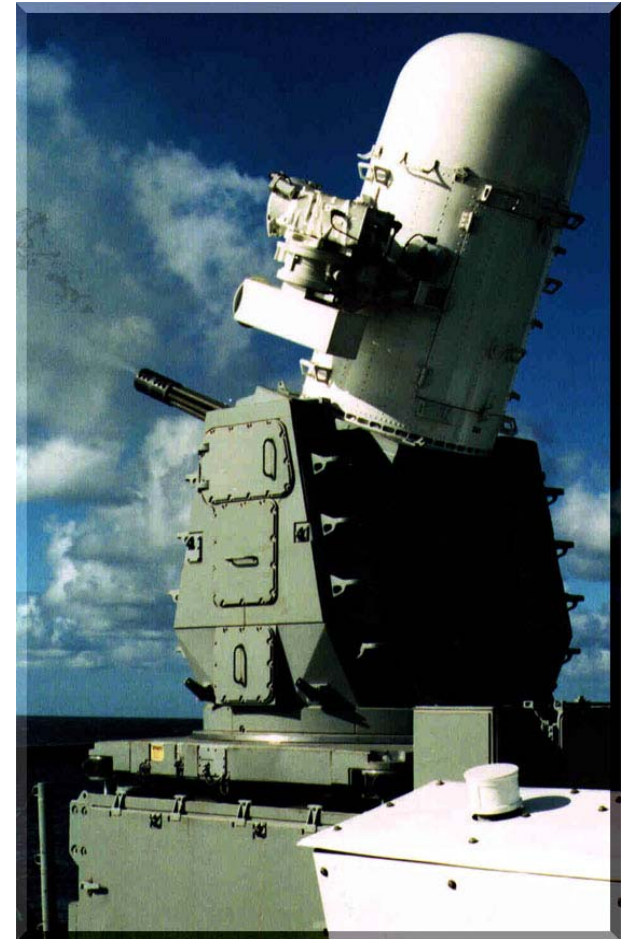
**Terminal Defense Against ASCMs and High Speed Aircraft Penetrating Other Fleet Defensive Envelopes**

## **Added Missions:**

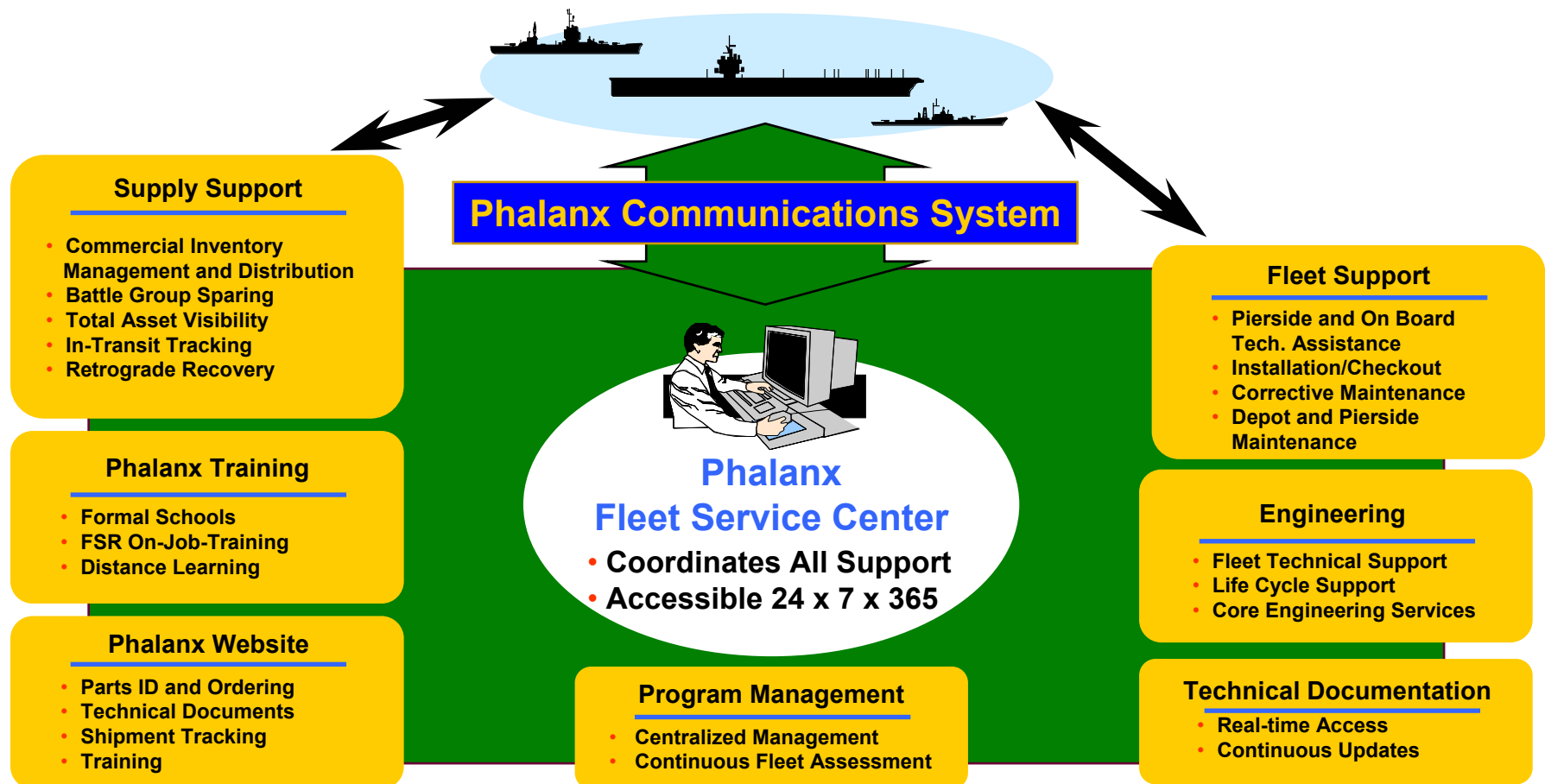
- **Surface Mode**
  - **Counter Small, Fast Surface Craft and Slow Flying Helicopters and Aircraft**
- **Sensor Support For Close-in Missile Engagements**

## **Benefits:**

- **Supports Multiple Roles In Ships Self Defense**
- **Man-in-the-Loop, Autonomous or Integrated Operation**
- **Fast Reaction**



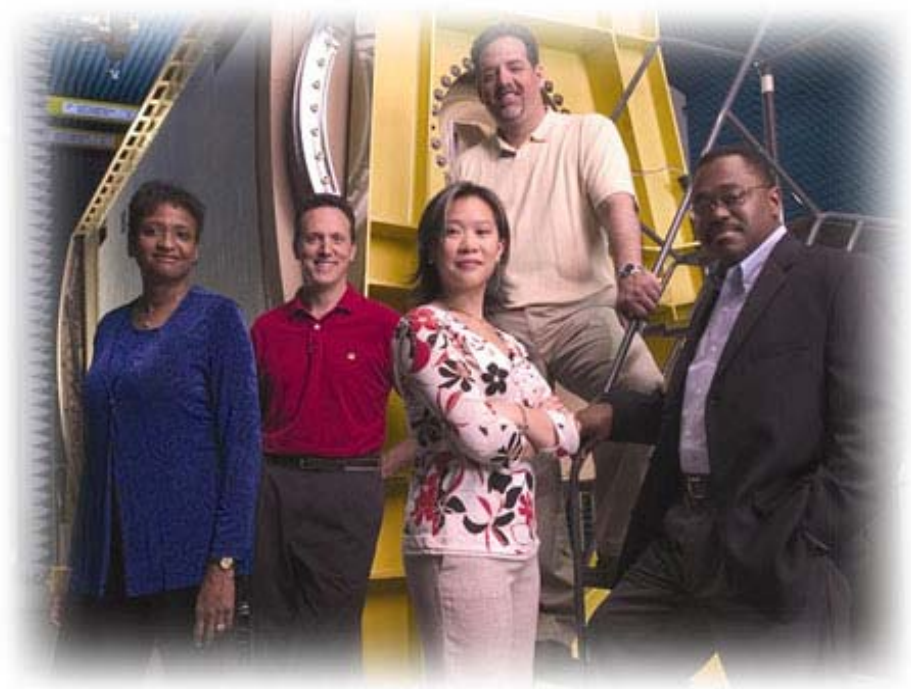
# Full Service Contractor Phalanx Life Cycle Support



**Raytheon Phalanx Life Cycle Support Provides Continuous, Worldwide, Support for Deployed and Non-Deployed Phalanx Systems**

# Engineering Challenges

- **Global competition for talent intensifying as innovation drives job growth in engineering, science fields**
- **In the U.S., fewer young people earning math & science degrees**
- **Generational challenges**
  - Aging workforce
  - Must appeal to younger workforce



**Demand Increasing, Supply Decreasing**

# Feeding The Pipeline

---

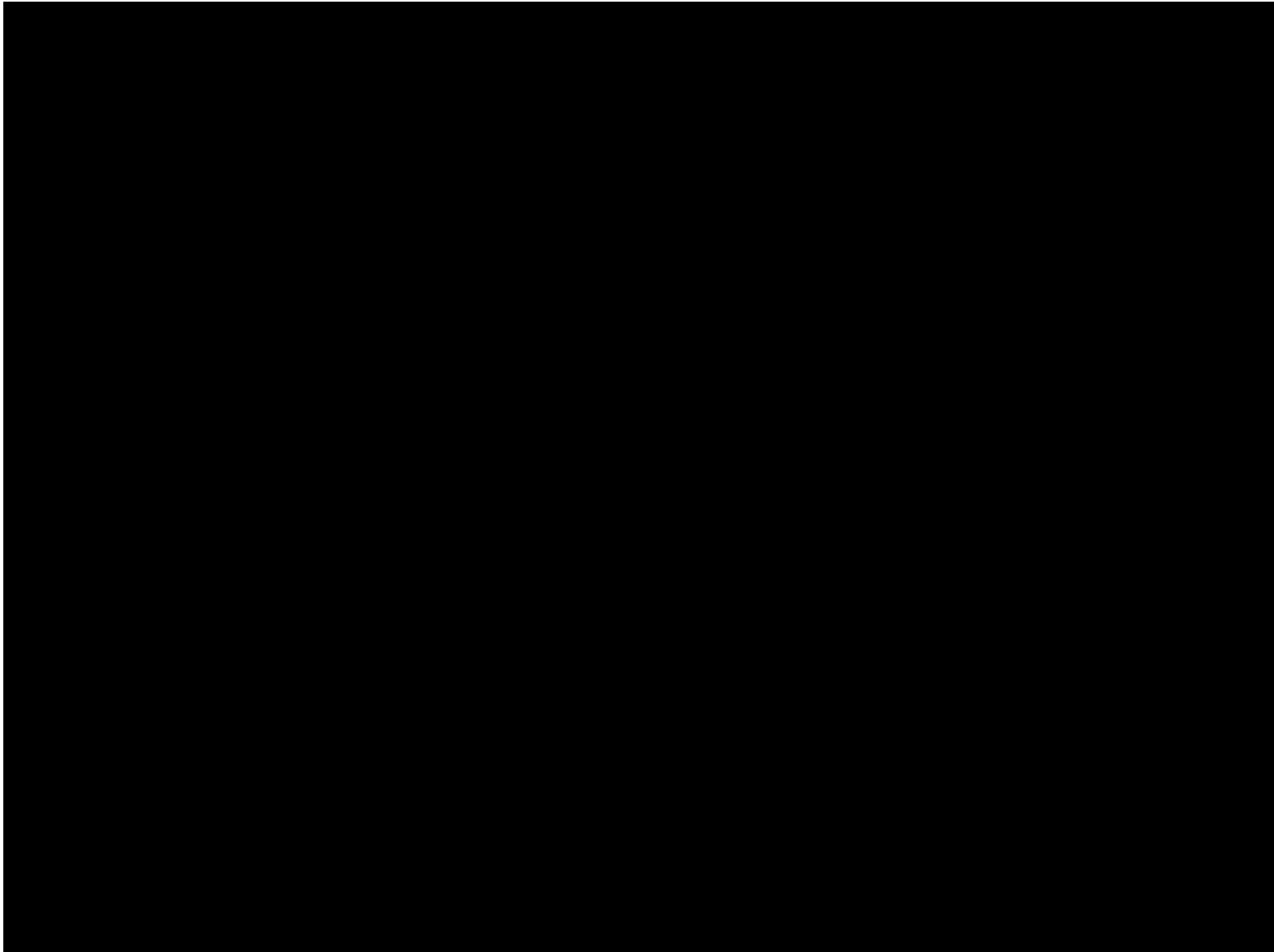
- **Must attract, engage diverse workforce**
- **Industry support/involvement in K-16 math, science education**
- **Partnerships with colleges, universities**
  - **Outstanding graduates**
  - **High-technology research**
  - **Post-graduate education**
  - **Creative continuing education programs**
  - **Outreach to the next generation**

**Industry/Education Partnerships Critical to Success**

***Customer  
Success  
Is Our  
Mission***

# **Customer Success Is Our Mission**

---



# ***Customer Success Is Our Mission***





# **The Modified Tank Ammunition**

## **IMI M152/6 HEAT - AP - T**

**National Defense Industrial Association  
40th Annual Armament Systems: GARM**

**New Orleans, LA**

**April 25-28, 2005**

**Danny Schirding**

**Chief Systems Engineer**

**Tank Ammunition Directorate - IMI Ammunition Group**

Israel Military Industries Ltd. (IMI)

P.O. Box 1044

Ramat Hasharon 47100, ISRAEL

**[dschirding@imi-israel.com](mailto:dschirding@imi-israel.com)**

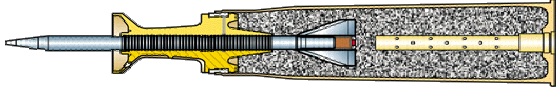
## The Main Operational Needs of Armor Corps

- ❖ To destroy Tanks and LAV's
- ❖ To breach and penetrate bunkers and buildings  
with maximum resulting damage
- ❖ **To incapacitate infantry, especially AT squads.**



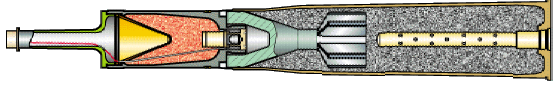


**KE**



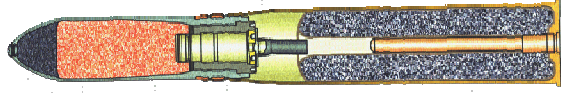
Heavy -  
armor

**HEAT**



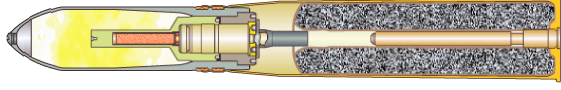
Medium and  
light armored  
vehicles and  
bunkers

**HEP/HESH**



Light armored  
vehicles and  
bunkers

**WP**



Screening  
and Spotting

**AP**



IMI  
solutions

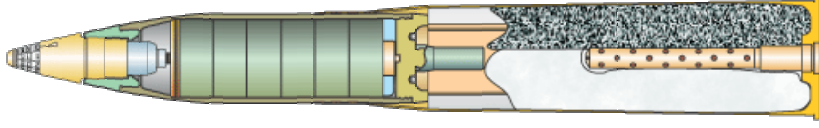
The current 105-mm family rounds



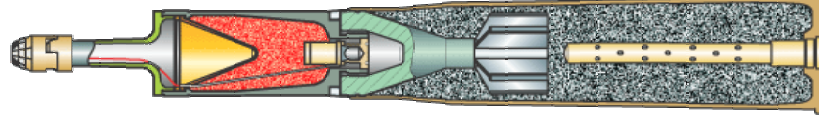
**STUN**



**APAM**



**M152/6**



The IMI AP rounds



## **Tank Stun Rounds - *Mission Statement***

- ❖ **A less than lethal tank round for use in low intensity conflicts.**
- ❖ **The round is designed to deter by creating a flash, bang and blast effect similar to service ammunition.**

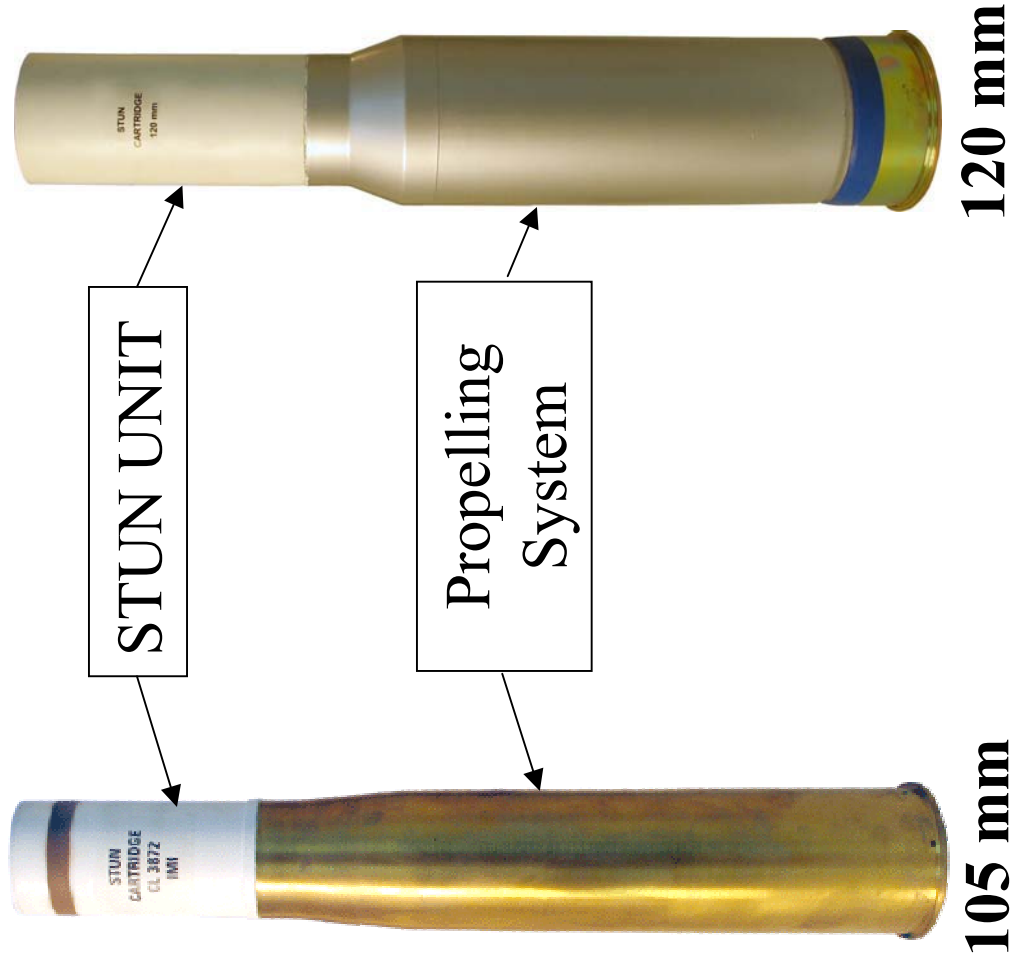


- ❖ The stun round gives the tank's crew the ability to be effective in situations such as:
  - Incidents involving non-combatants
  - Armed terrorists hiding behind a crowd
  - Hostile civilians (mob) trying to approach/climb on the tank





## 105 mm & 120 mm STUN rounds (Less-Than-Lethal tank round)



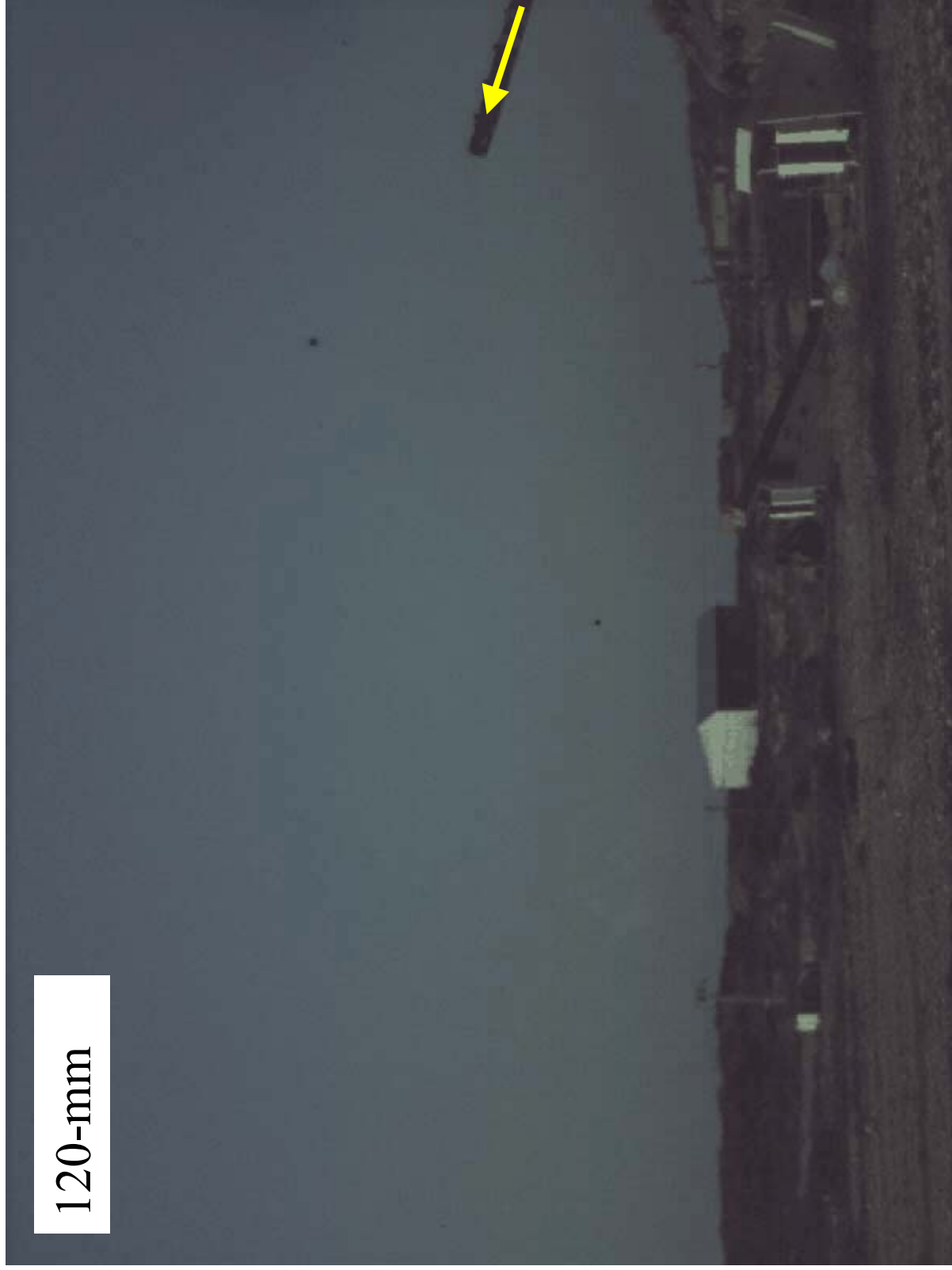


## Video film of the firing test – 105 mm





120-mm





# APAM

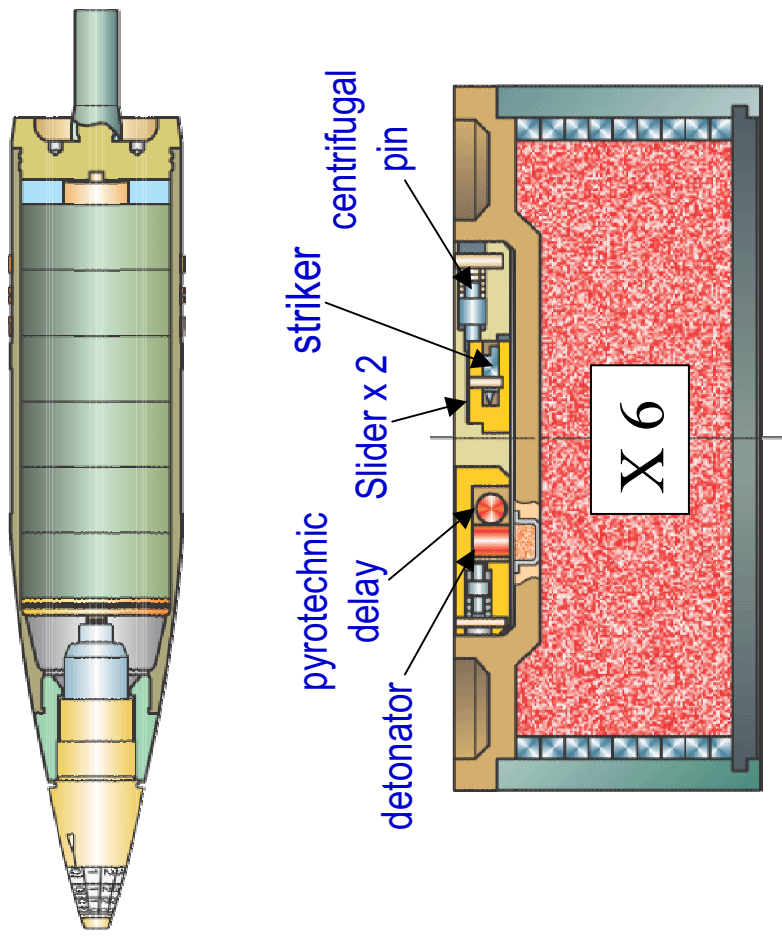
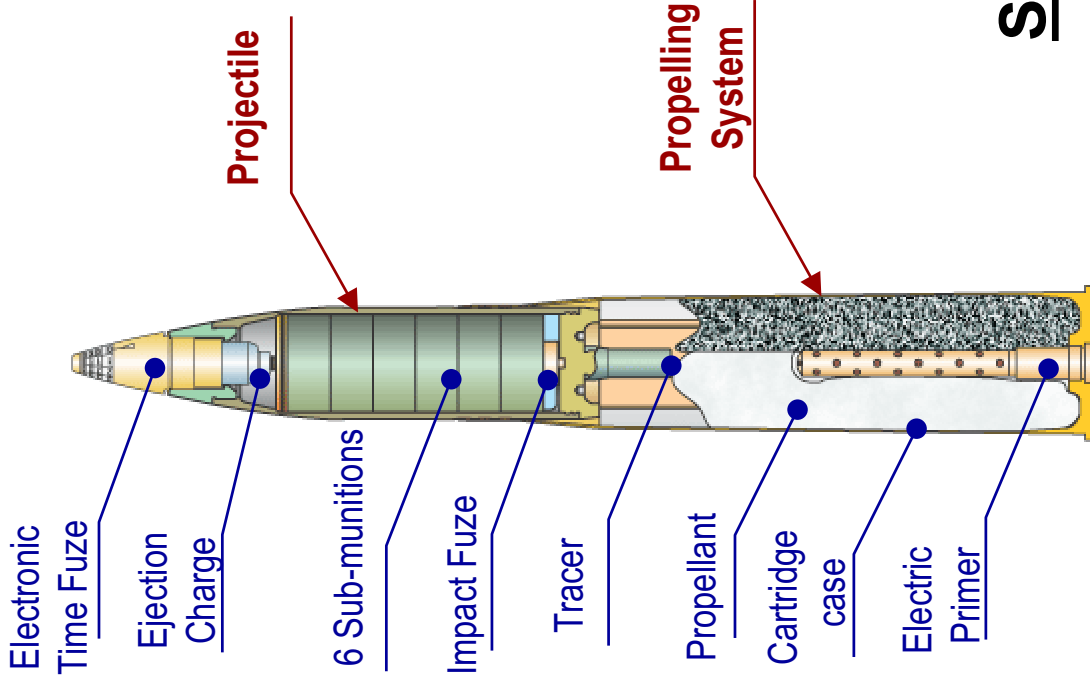
**Anti-Personnel/**

**Anti-Materiel**

**105-mm Tank Round**



# APAM – Anti-Personnel/Anti-Materiel



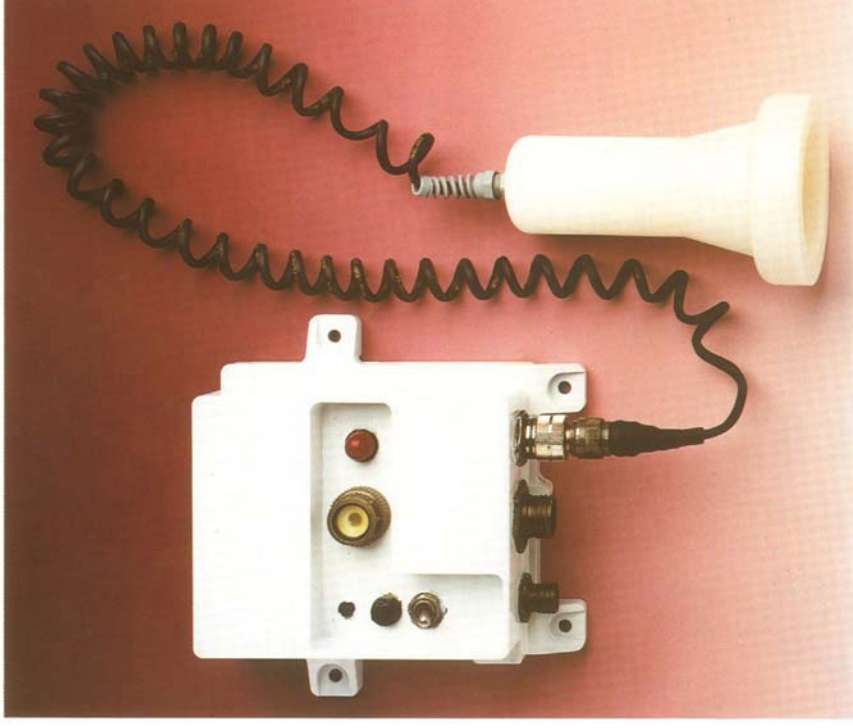
**Status: 105 mm in operational use.**

# Fuze Setting

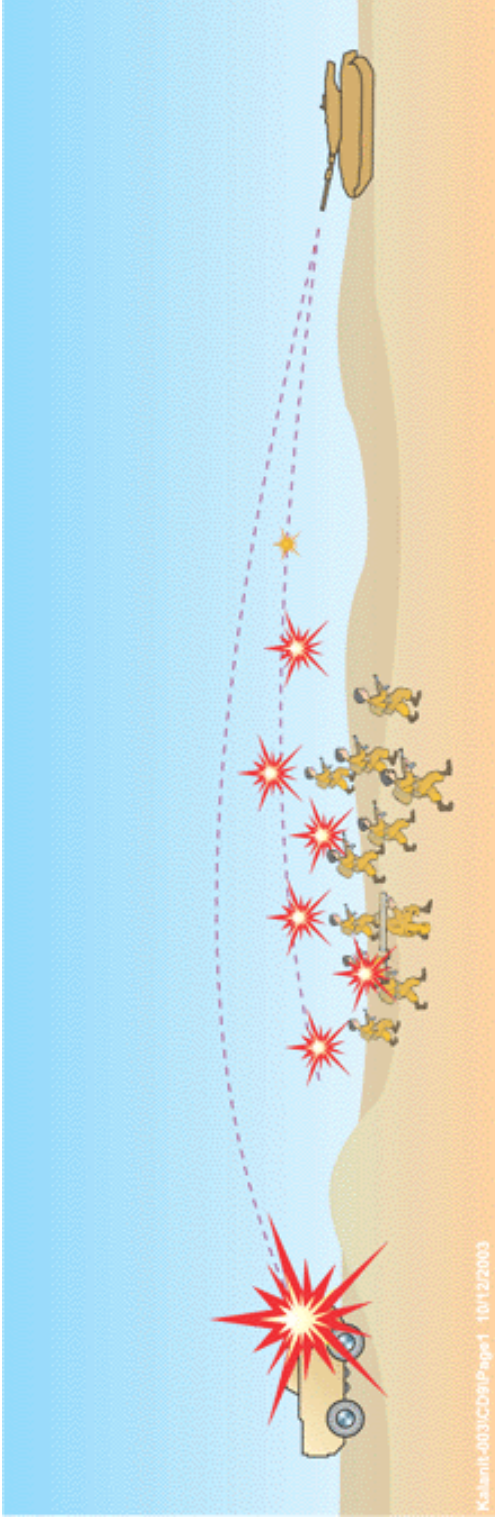
## Manual fuze setting



## Semi-automatic fuze setter Inductive Fuze Setter (IFS)



## APAM – Basic Modes of Operation



❖ **Ejection Mode** - Ejected sub-munitions explode sequentially in the air after separation.

➤ **Anti-Personnel**      ➤ **Anti-Helicopter**

❖ **Impact Mode** – Entire projectile explodes as a unitary warhead upon impact.

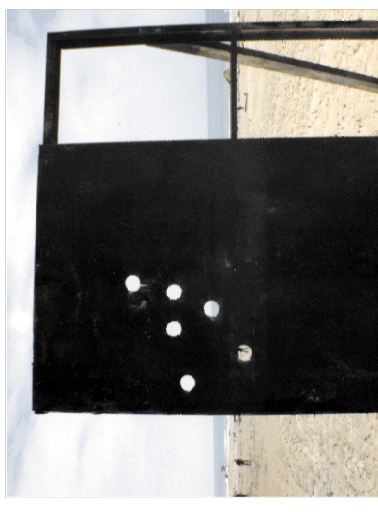
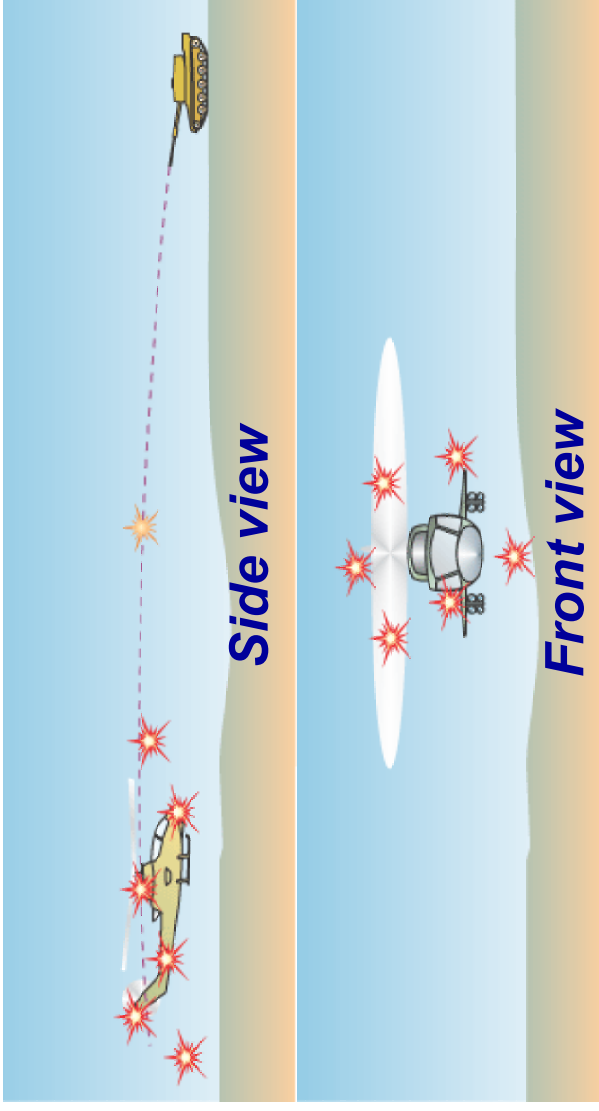
➤ **LAV's**      ➤ **Bunkers & Buildings**

## AP MODE (EJECTION) DYNAMIC ARENA TEST



❖ High effectiveness against hidden and prone targets

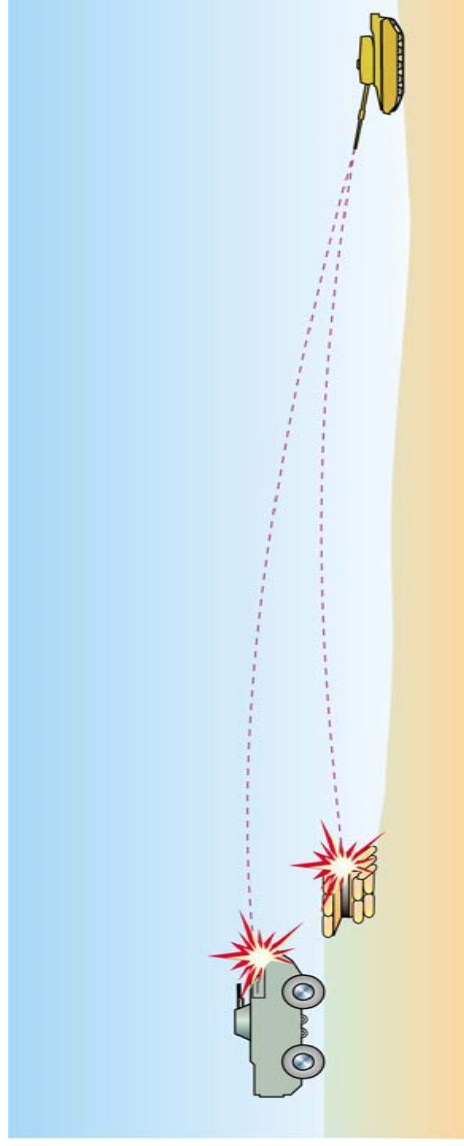
# ANTI-HELICOPTER MODE



PENETRATION OF 10 mm  
RHA TARGET  
BY SUBMUNITIONS

- ❖ Six submunitions (and the projectile body & base) fly towards the target. One hit is good enough.
- ❖ Even in a near miss, the helicopter pilot will see and/or feel the detonations, causing mission abort.

## AM MODE (IMPACT)



- ❖ **Projectile will penetrate LAV's and Bunkers.**
- ❖ **High density of lethal fragments inside.**



**Light armor**



**Double reinforced concrete wall**



**Hits on witness plate**



## APAM 105 - Damage to Sand & Timber Bunker



1 ROUND



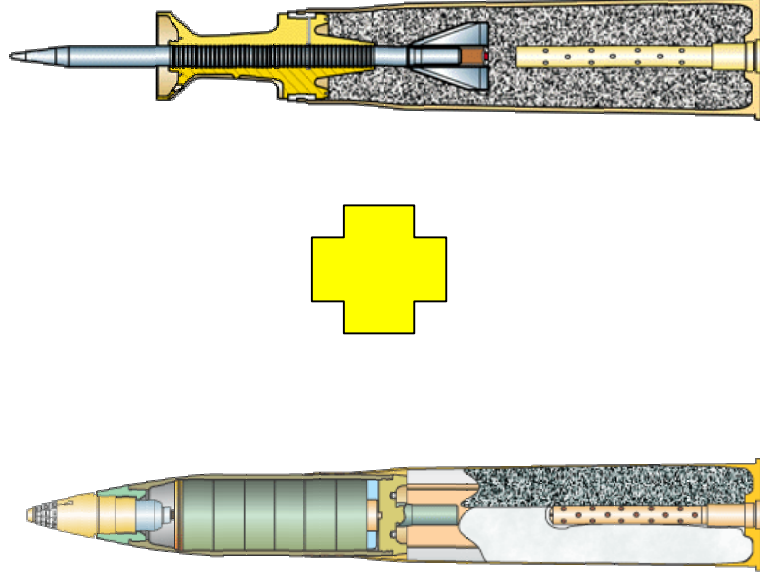
## The Optimal Solution !

**Infantry,**

**LAVs,**

**Bunkers & Buildings,**

**Helicopters.**



**Armor**

- ❖ **Maximum capability with minimum rounds.**
- ❖ **Reduced logistic load.**

## The alternative... !

**Armies around the world have large stocks of 105-mm  
HEAT rounds (M456 / IMI M152/3)**

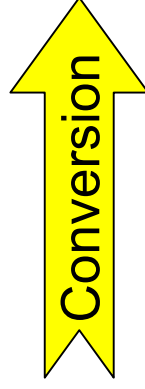
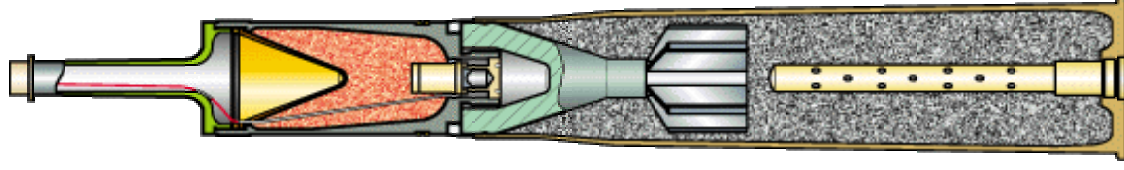
❖ IMI's alternative solution -

### Upgrading HEAT rounds

- Using the old and well known type of ammunition
- Enhance capabilities
- Improve reliability
- Improve safety
- Cost – effective (high kill probability)
- Providing Armor Corps needs

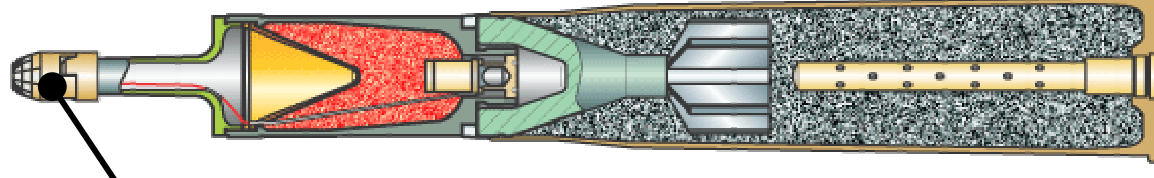


**M456 /**  
**IMI M152/3**



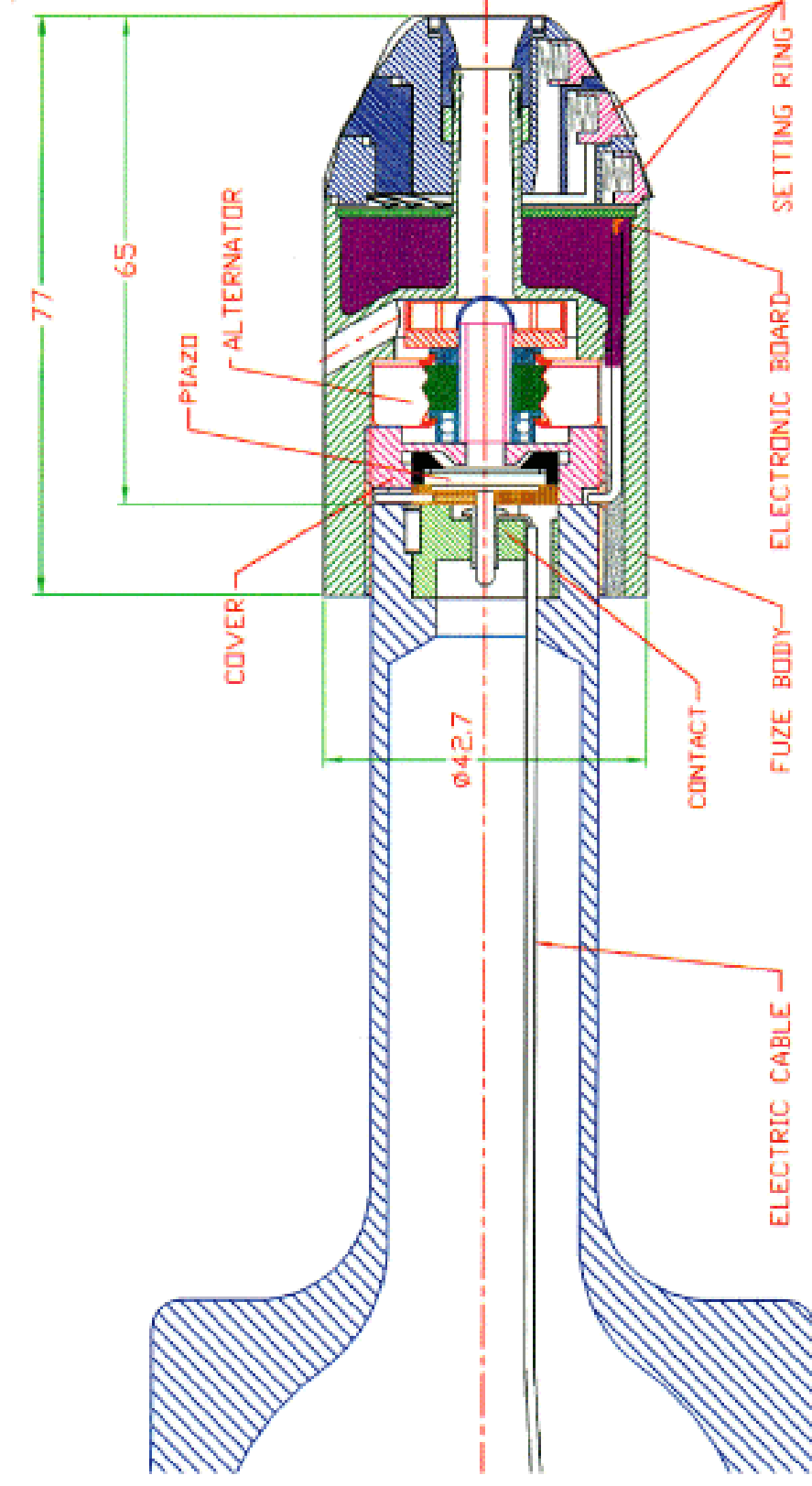
**Electronic  
Device  
“FUZAMAN”**

**IMI M152/6**

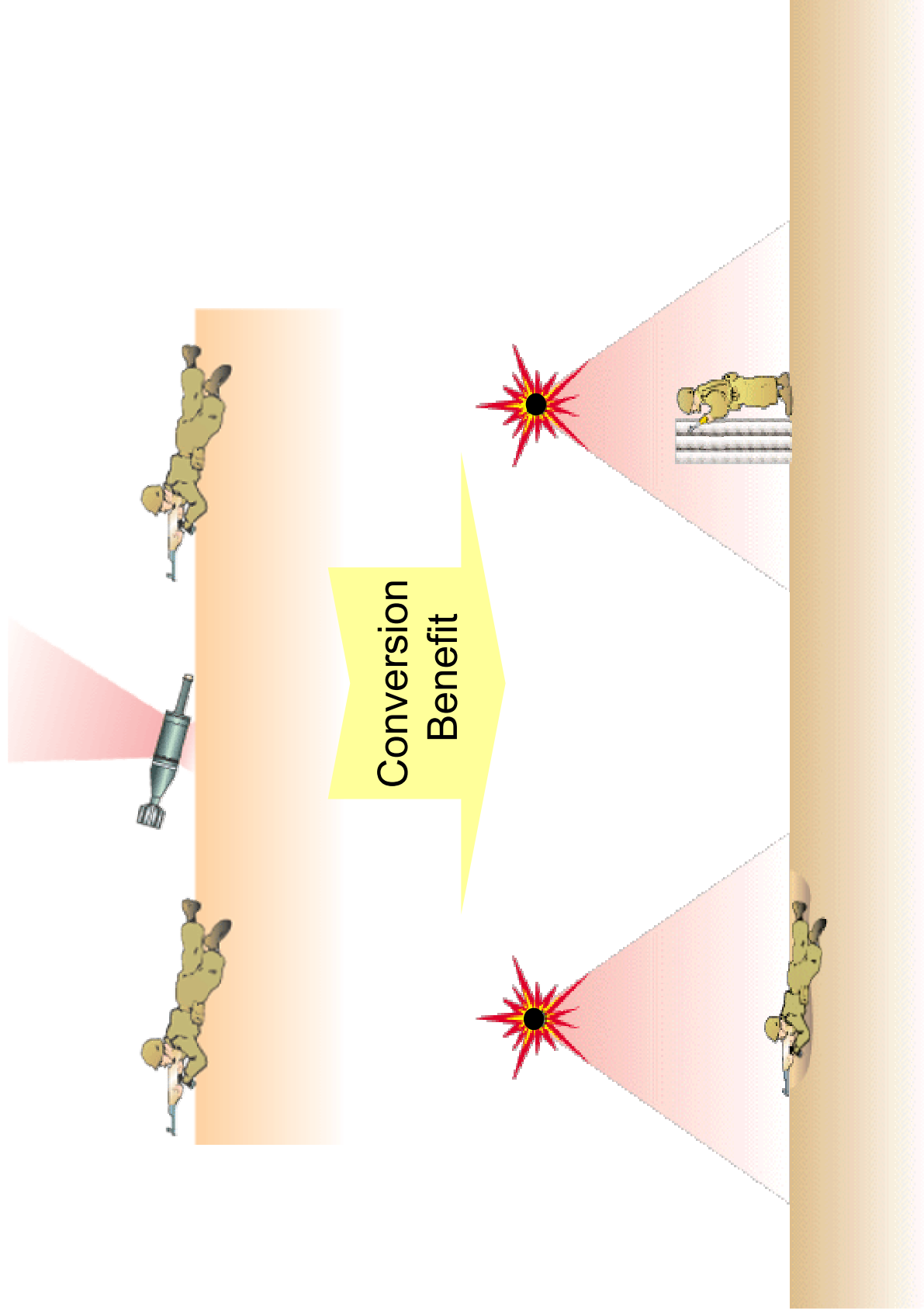




# **“FUZAMAN”** ***High – Reliability Electronic Time Device***

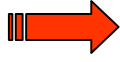


**RESHEF TECHNOLOGIES, LTD.**  
**AN ARYT COMPANY**



### ❖ Influence on the aeroballistics performance:

- Drag Force
- Lift Force
- Static and Dynamic Stability
- Jump



**Trajectory  
Dispersion  
(Accuracy)**

### ❖ Influence on the final ballistic



**Penetration**

**Is it that simple?**

### ❖ The operational benefits:

- Warhead detonation above the ground – AP mode
- Warhead detonation upon impact and grazing (reliability and safety)
- Multi-purpose capability

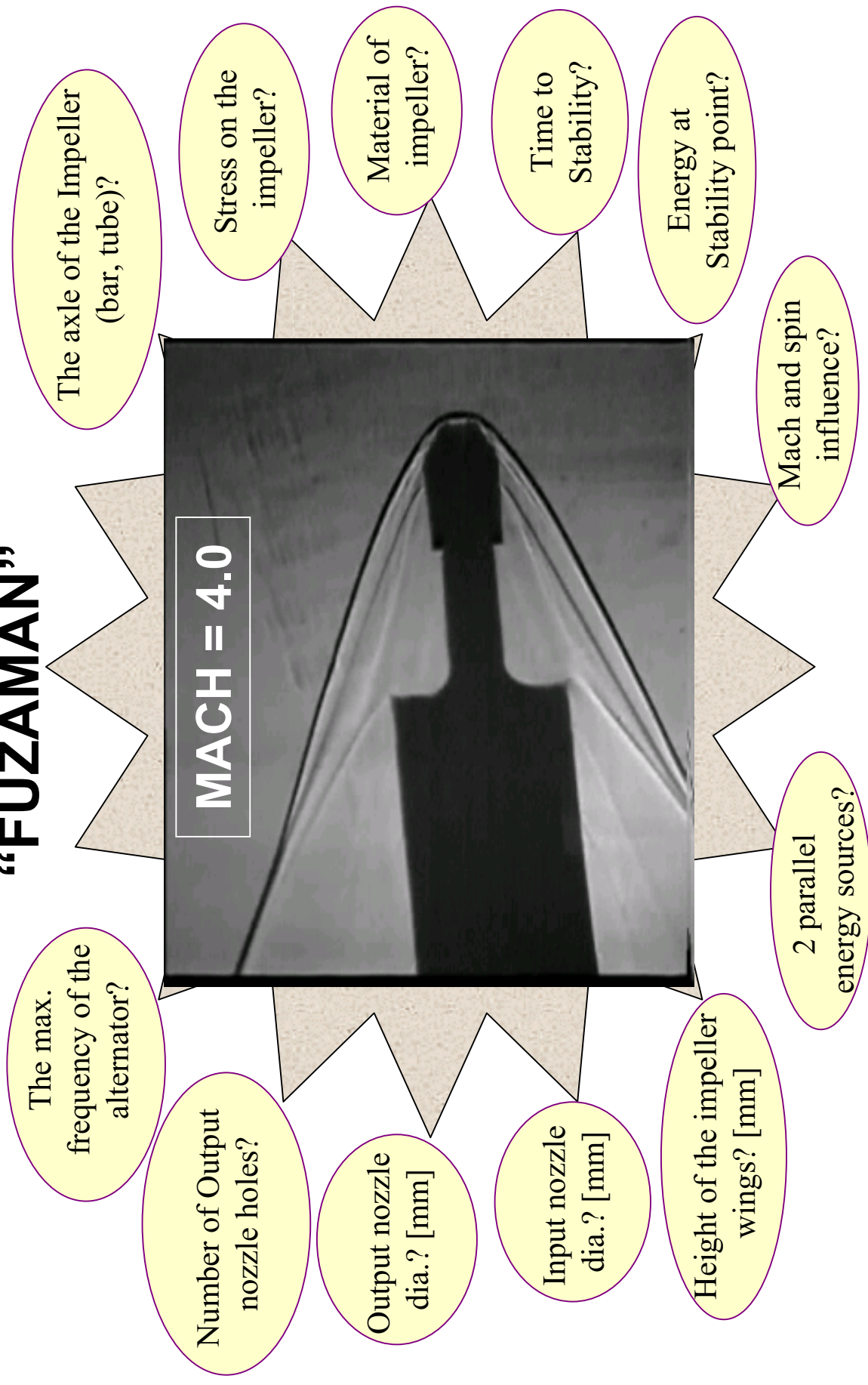


**Improvements**



# ***Research and Development Activities***

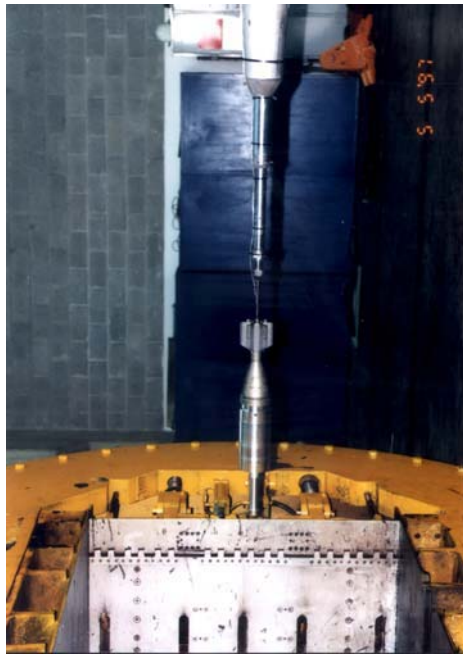
# Preliminary analysis and wind tunnel tests for the “FUZAMAN”

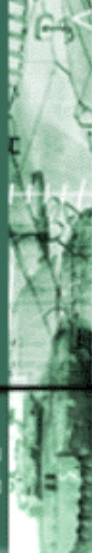


# Aeroballistics analysis and wind tunnel tests for the Projectile of IMI M152/6

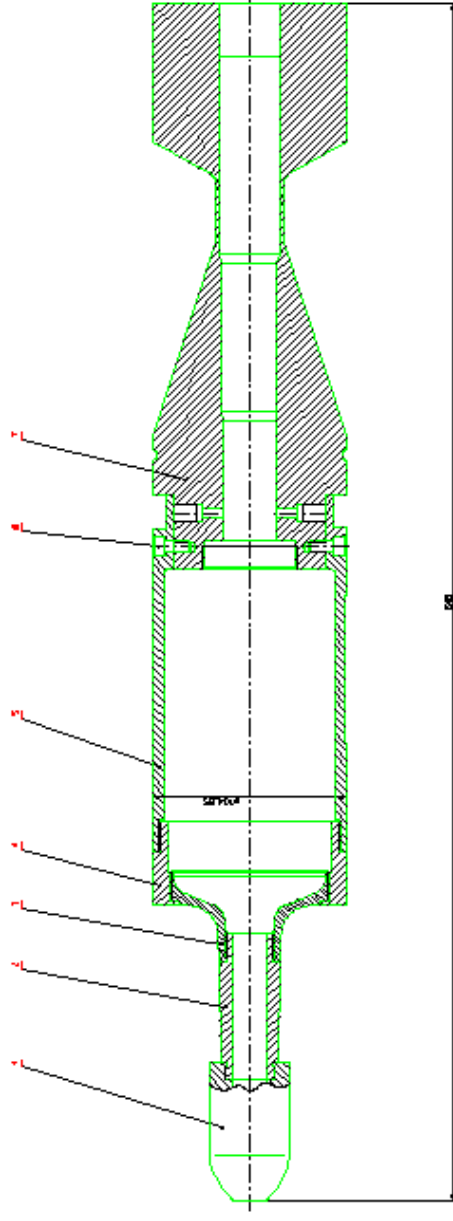
## ❖ Wind tunnel tests

- Mach numbers: 1.2, 1.6, 2.0, 2.2, 2.6, 2.8
- Angle of attack:  $-7^\circ \leq \alpha \leq +7^\circ$
- $C_d$  vs Mach
- Aerodynamic coefficients ( $C_{ma}$ ,  $C_{na}$ ,  $C_{roll}$ ,  $C_{l\alpha}$  etc.)
- $X_{cp}$  –  $X_{cg}$  (static stability)

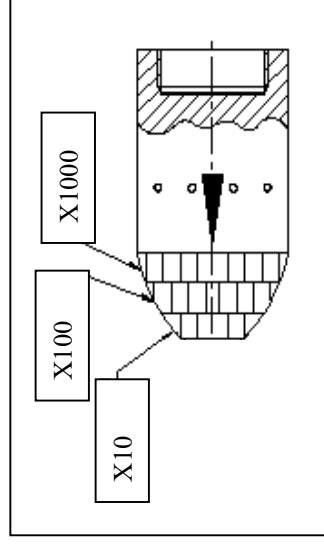




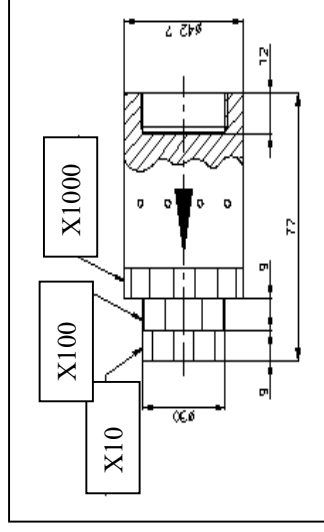
## Prototypes for Wind tunnel:



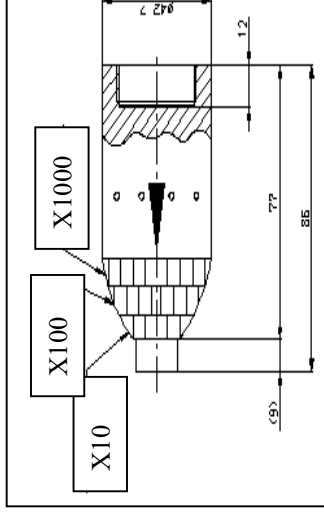
Type No. 1



Type No. 2



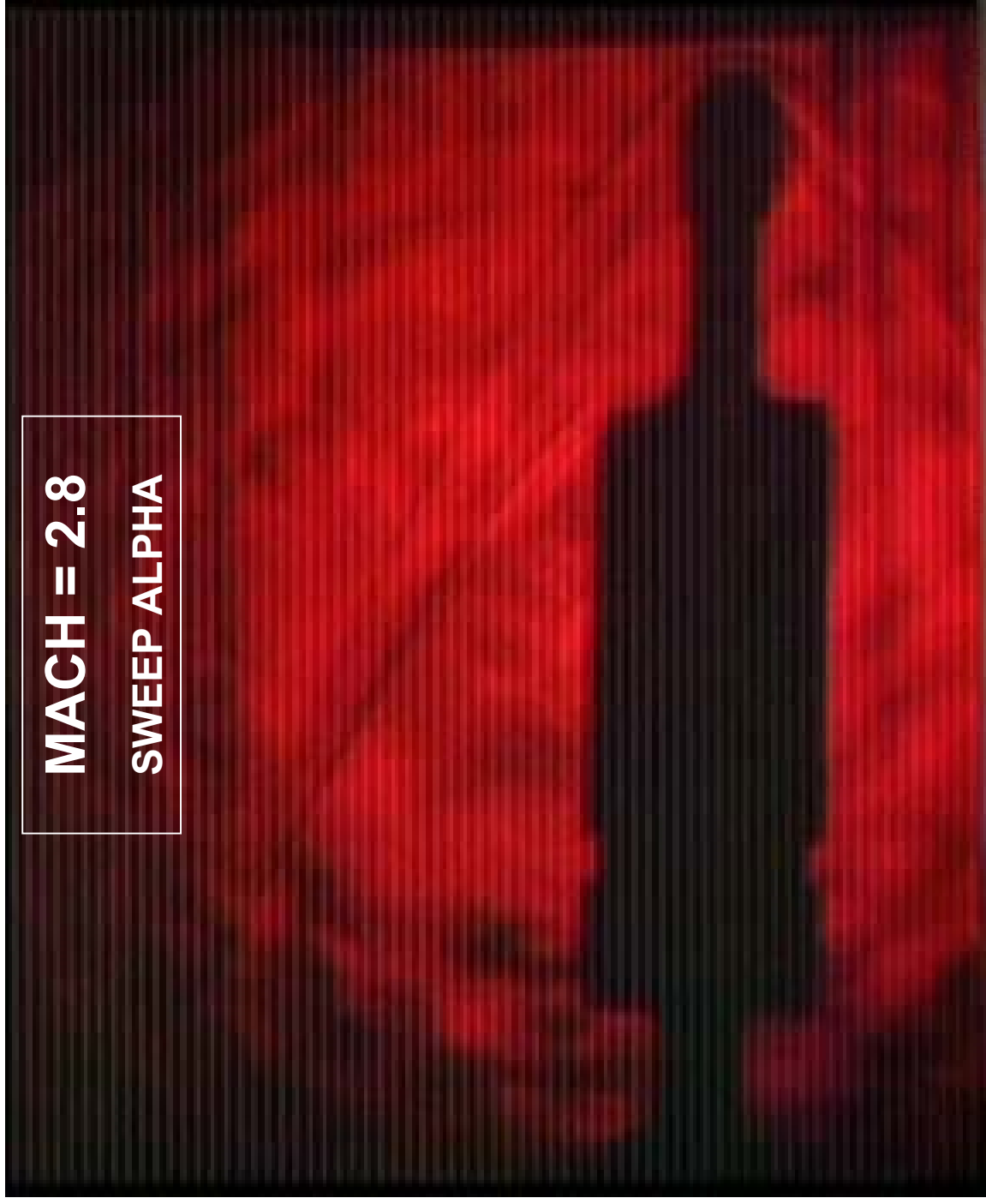
Type No. 3





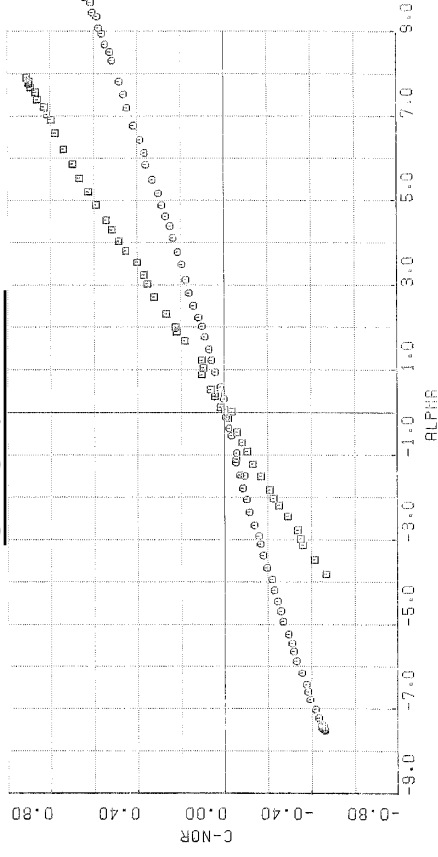
**MACH = 2.8**

**SWEEP ALPHA**

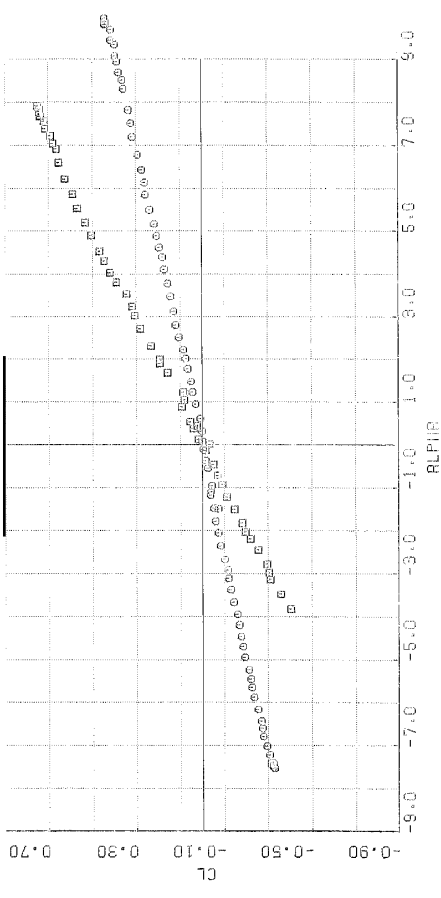




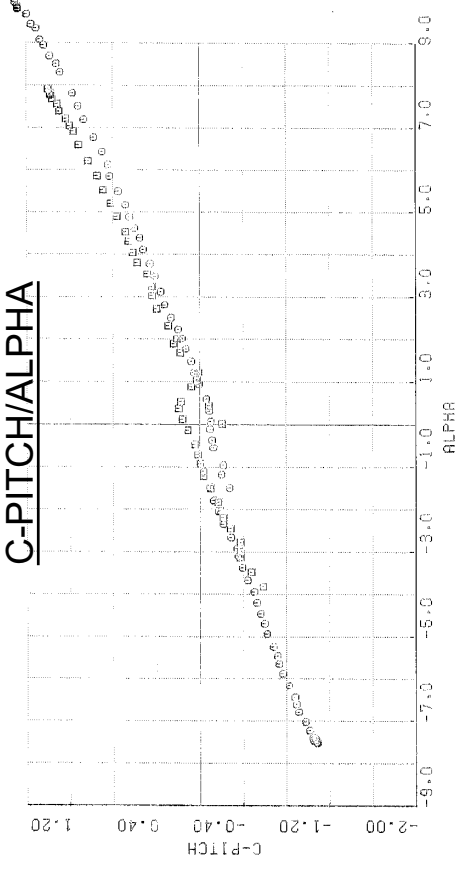
C-NOR/ALPHA



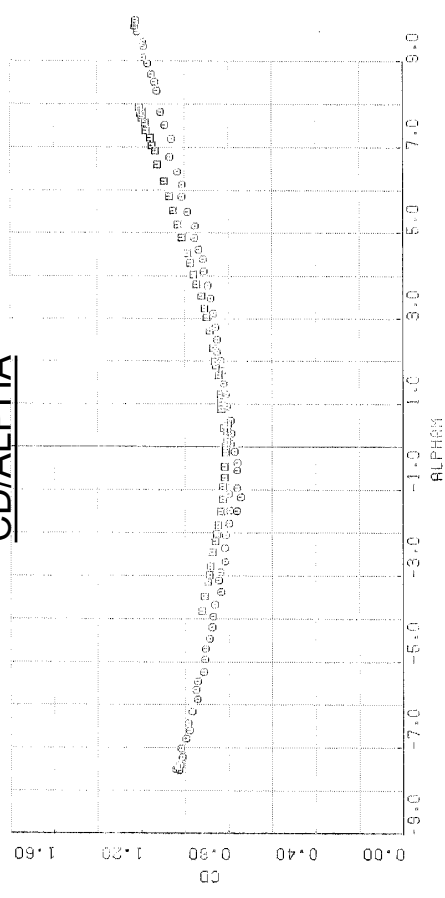
CL/ALPHA



C-PITCH/ALPHA

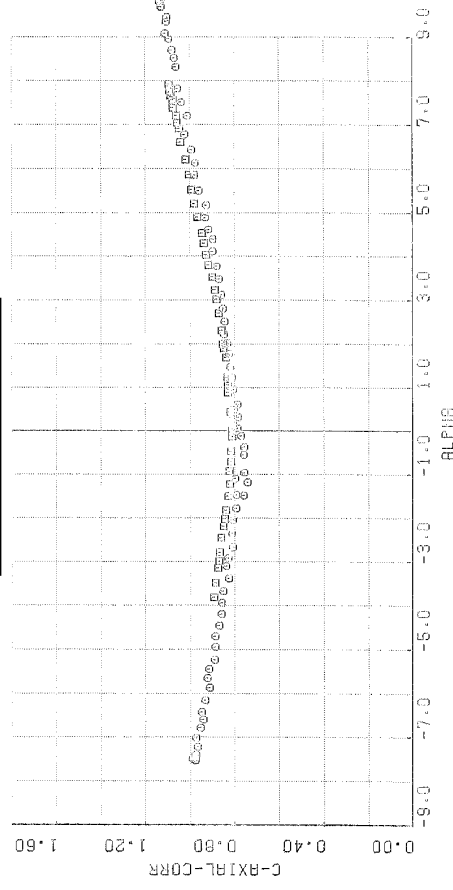


CD/ALPHA

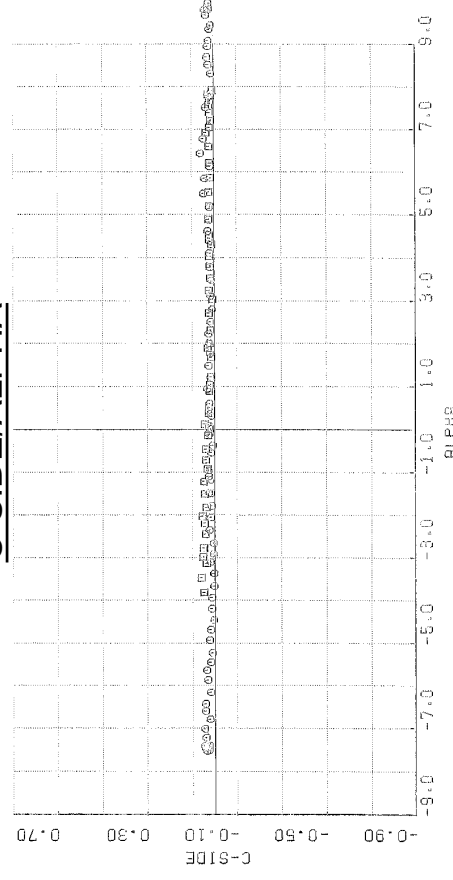




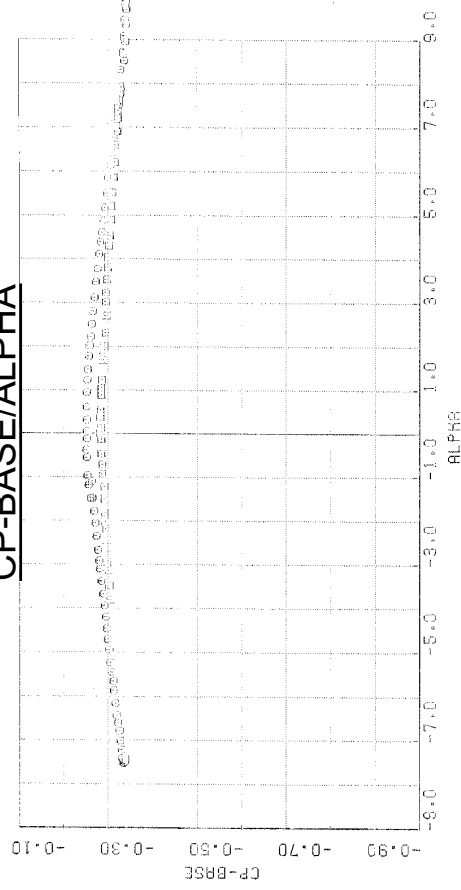
C-AXIAL/ALPHA



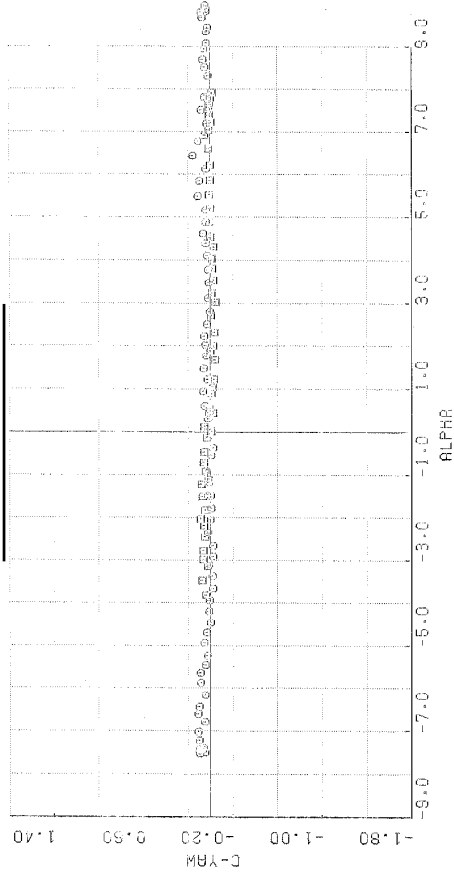
C-SIDE/ALPHA



CP-BASE/ALPHA

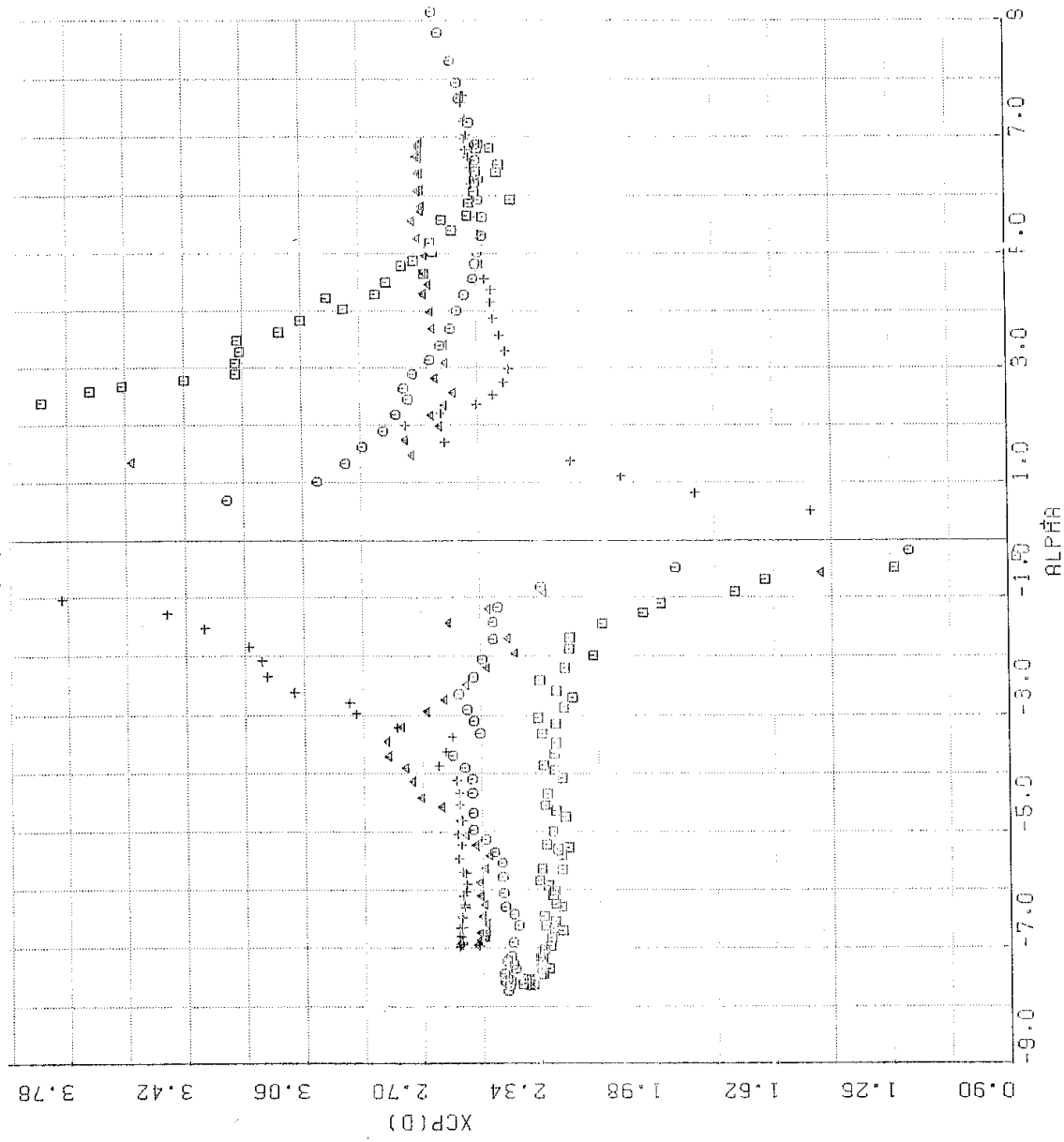


C-YAW/ALPHA





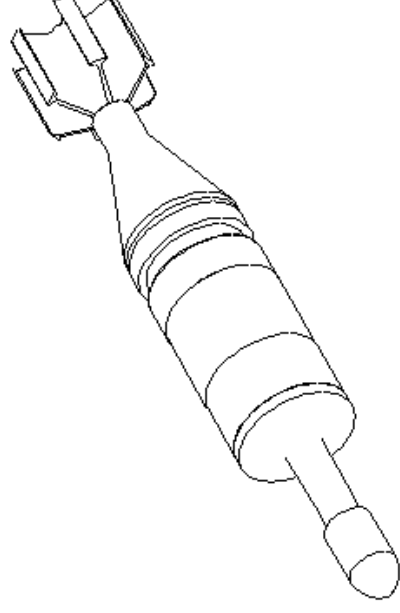
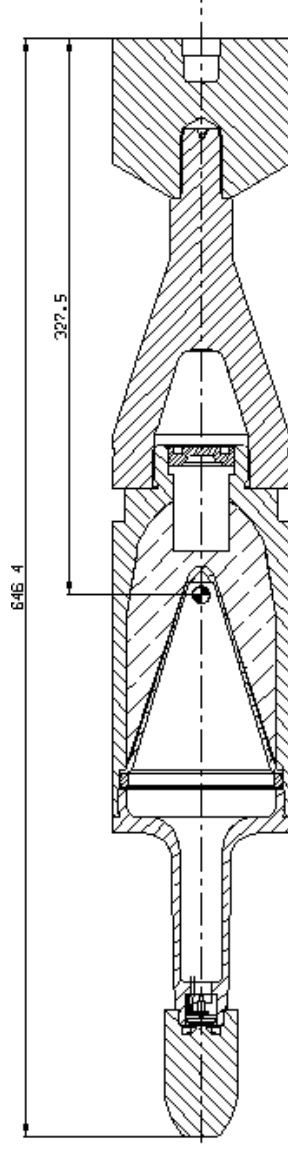
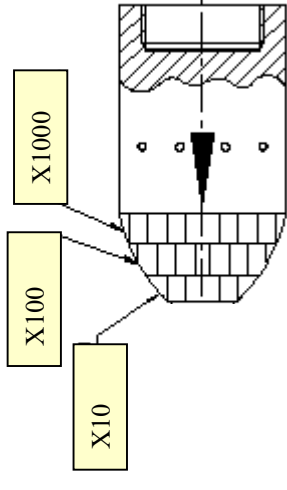
## XCP(D)/ALPHA



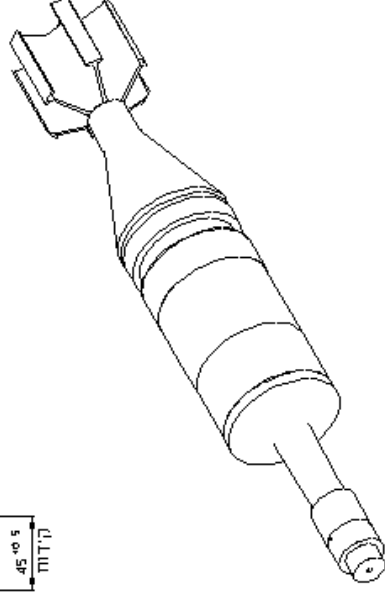


# External Ballistics test - IMI M152/6

## Prototype No. 1

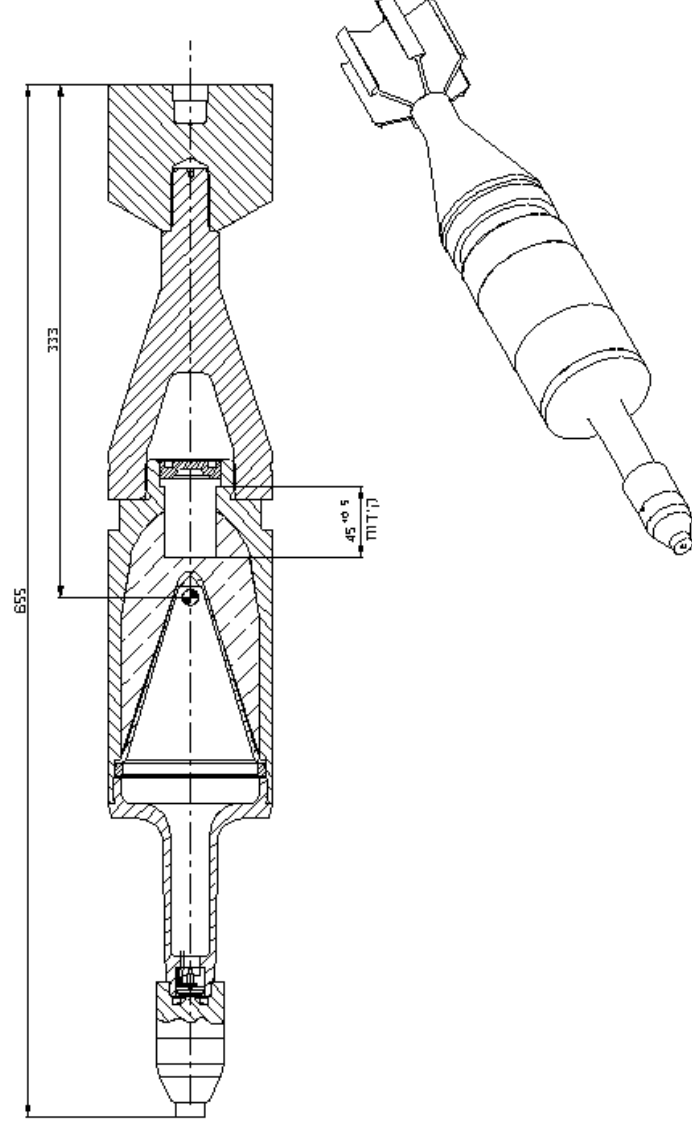
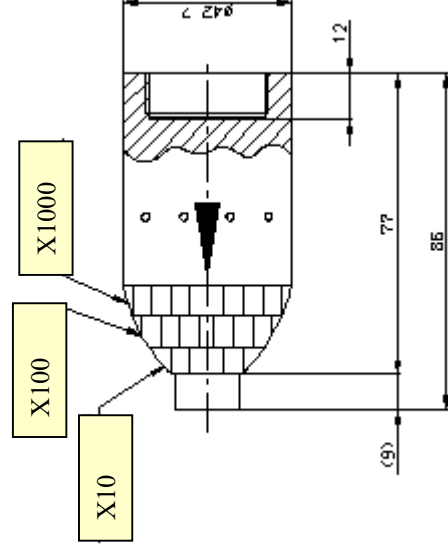


## Prototype No. 2





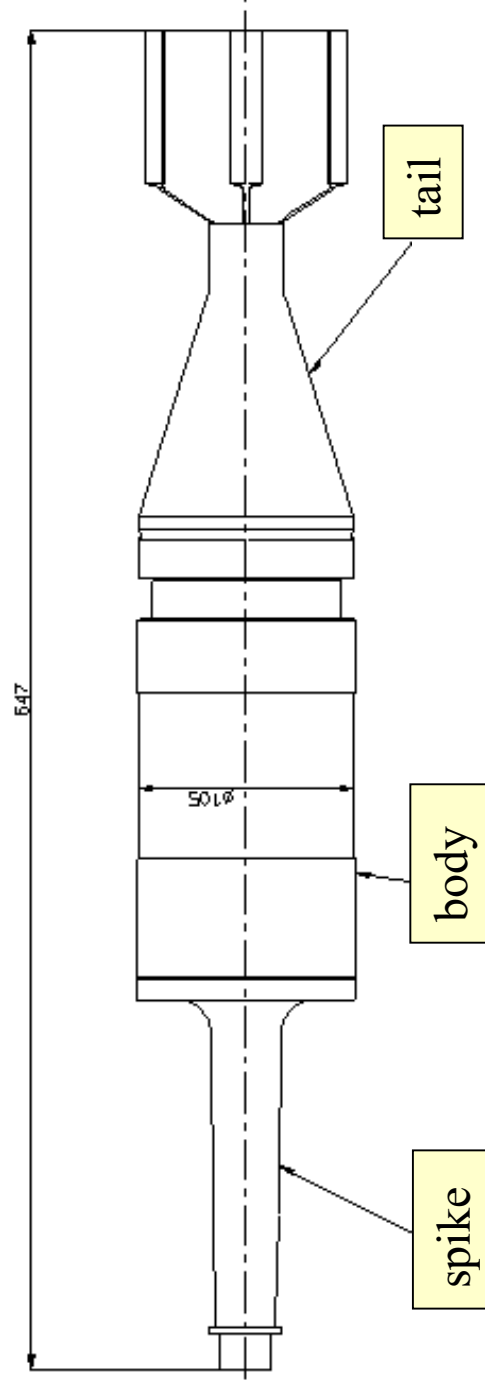
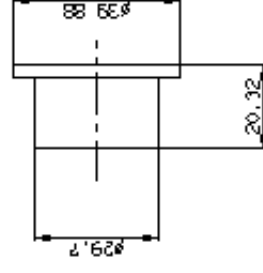
## Prototype No. 3





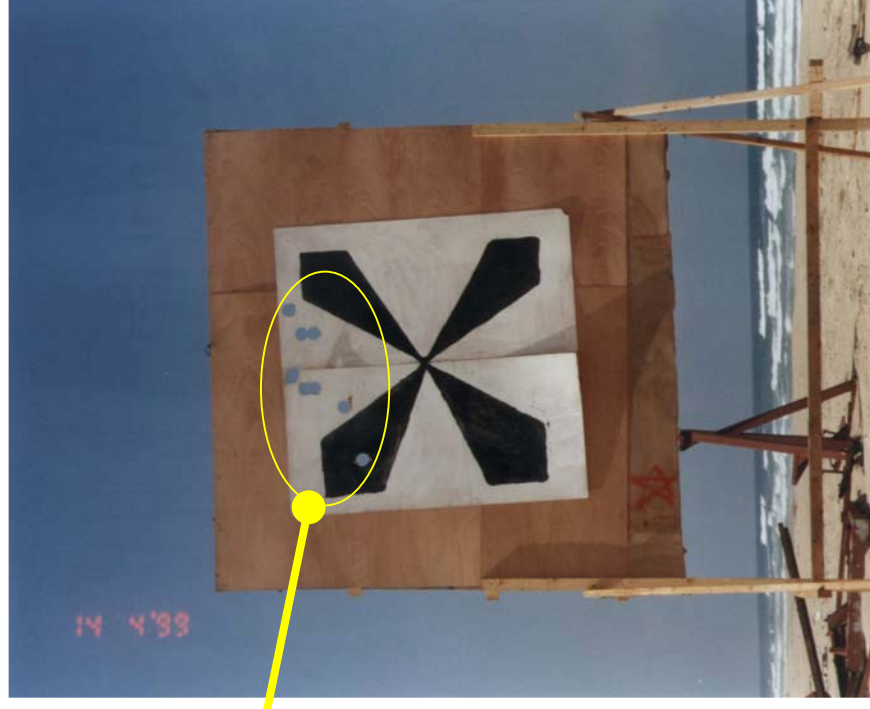
## **M456 / IMI M152/3**

**(Reference)**



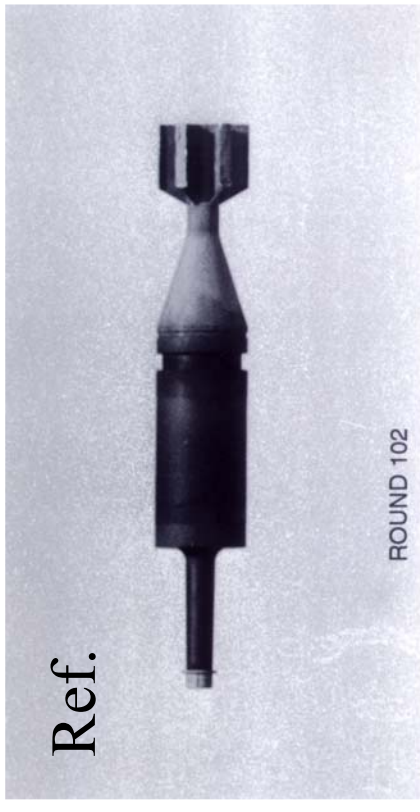
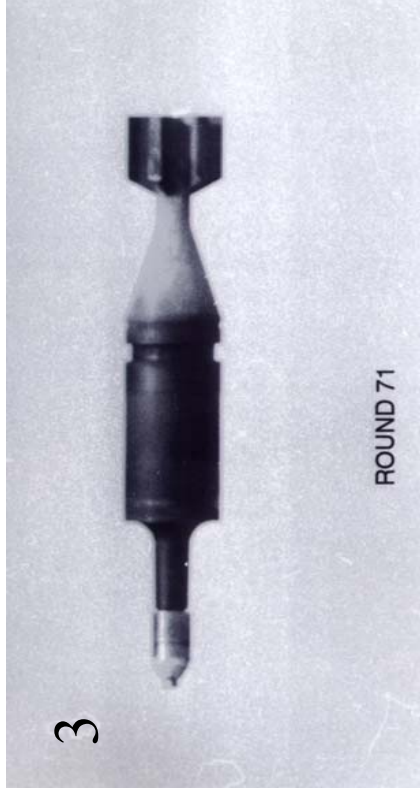
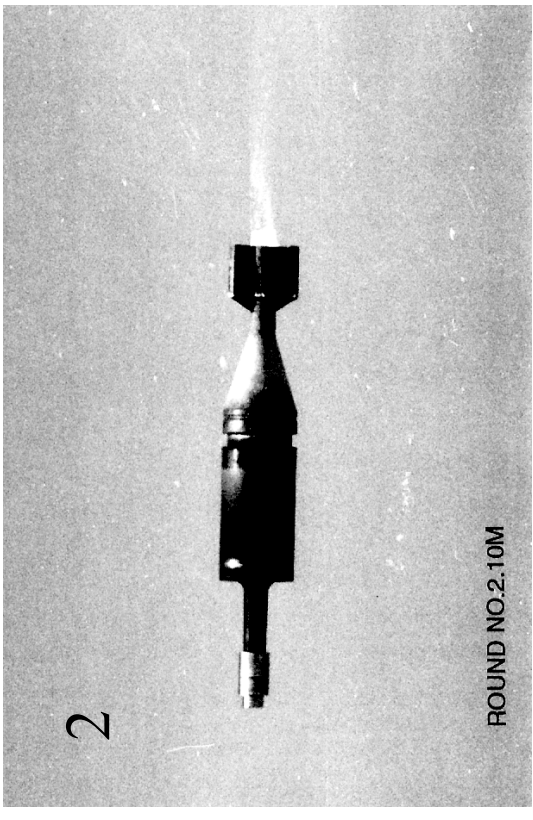
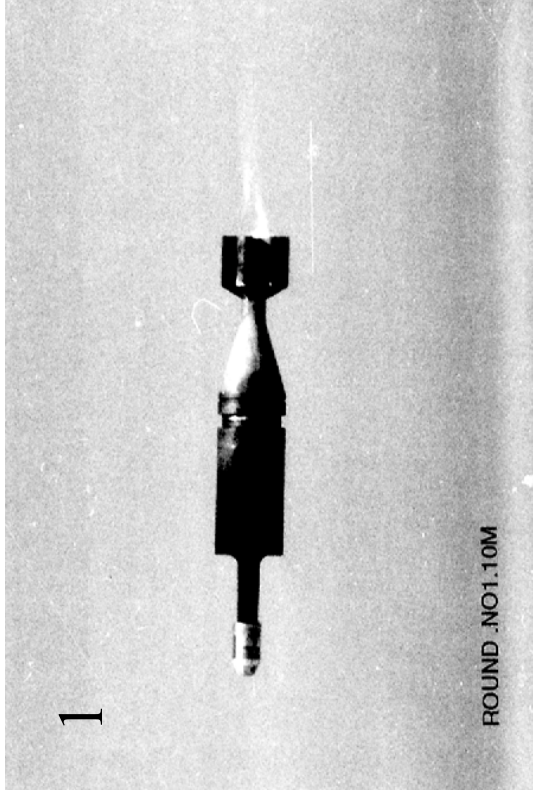


## ❖ Dispersion / accuracy (2,000 m)



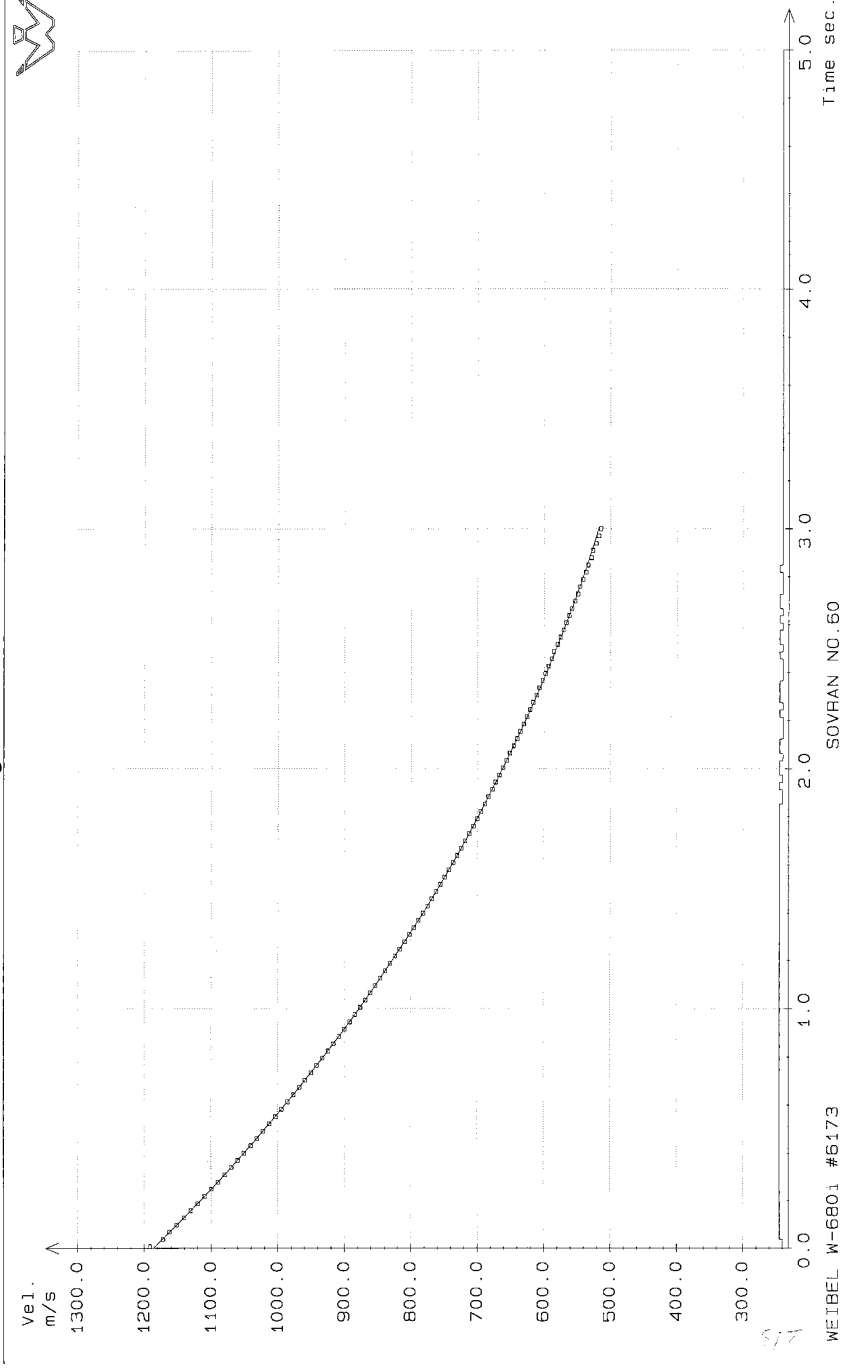


## ❖ Ballistically matched trajectory





## Velocity vs. Time



## Final Ballistics test - IMI M152/6

### ❖ Safety Firing Test

- Simulated cartridge with pyrotechnic (flash) composition

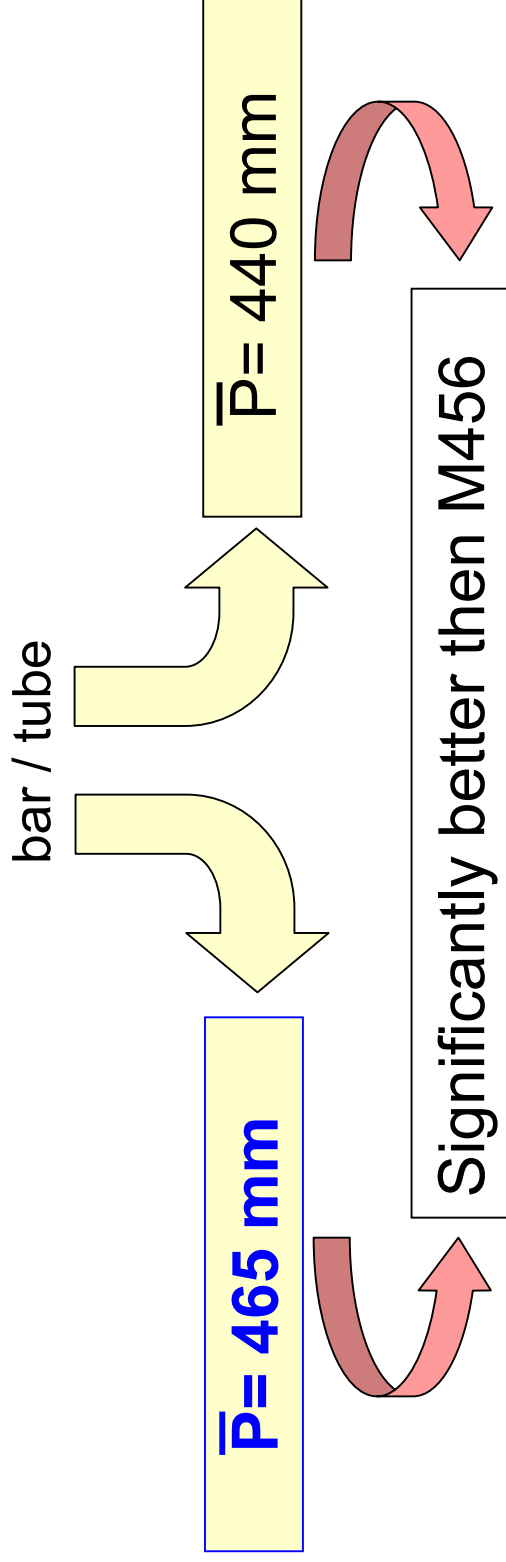


## ❖ Firing test – Yaw

- Wave length
- Dynamic stability

## ❖ Penetration tests

- M152/3 warhead
- RHA target (225 mm plate at 120-m from the muzzle)
- 60° NATO
- Alternator axle in the “FUZAMAN”:





**Front Side**



**Back Side**





## ❖ Dynamic arena test (AP mode)

1



2



3





## ❖ Reliability - Detonation above the ground (AP mode)

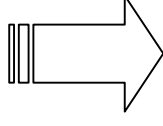


## ❖ Operational Research -

- *Lethal Area - 20x50 m*
- *Criteria: Personnel Enemy*  
*Standing / Prone 30" assault*
- *Firing: 1 round / series of 3 rounds*
- *Remaining velocity - 855 m/sec*  
*(2,000 m)*
- *Angle of fall - 0.3 deg.*

## ❖ Results -

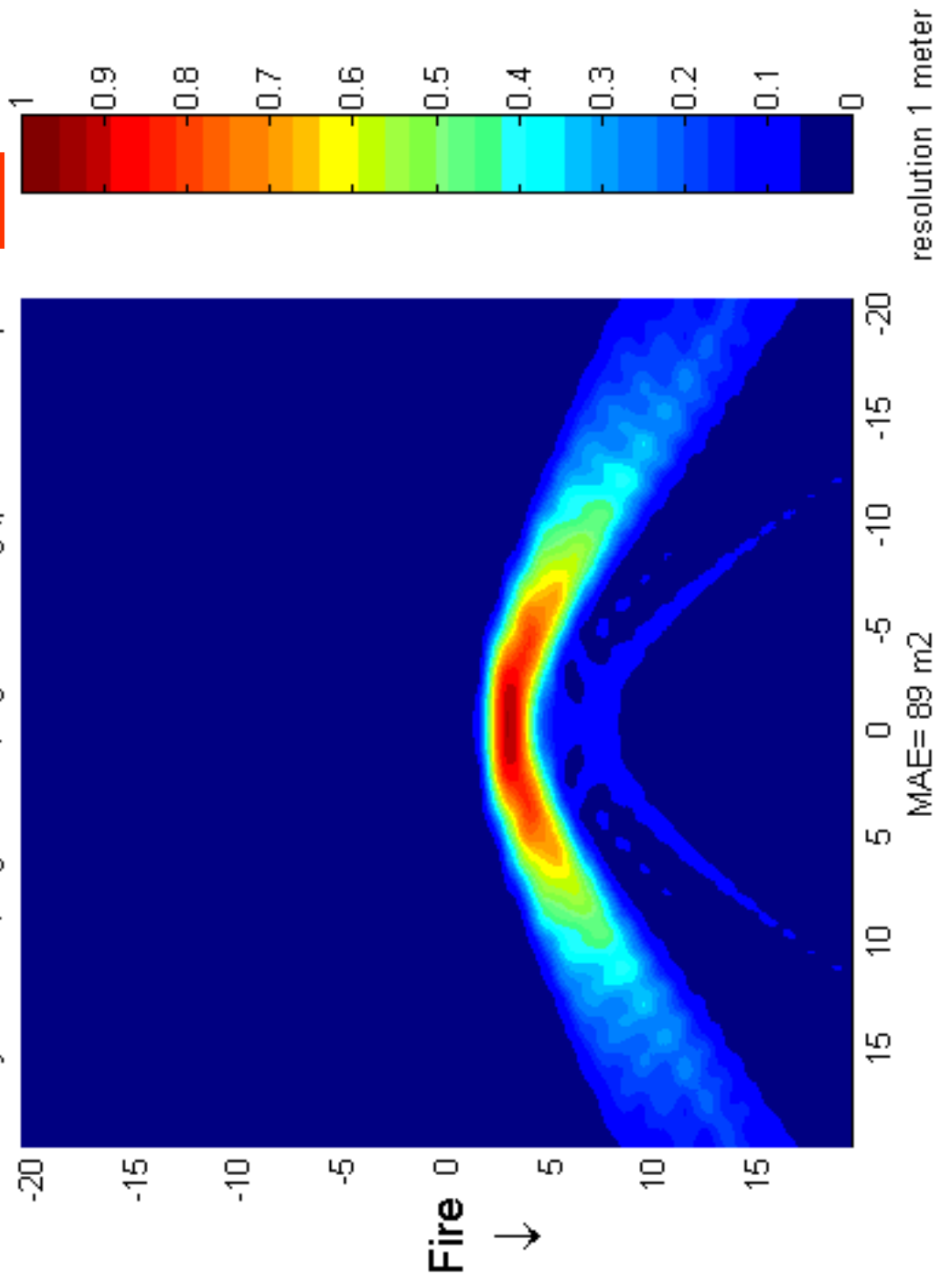
- ✓ The optimal height of detonation (above ground) - 6 m
- ✓ Mean Area of Effectiveness (MAE) / Lethal Area and Incapacitation Probability Maps





## Incapacitation Probability ( $\rho_k$ ) Map

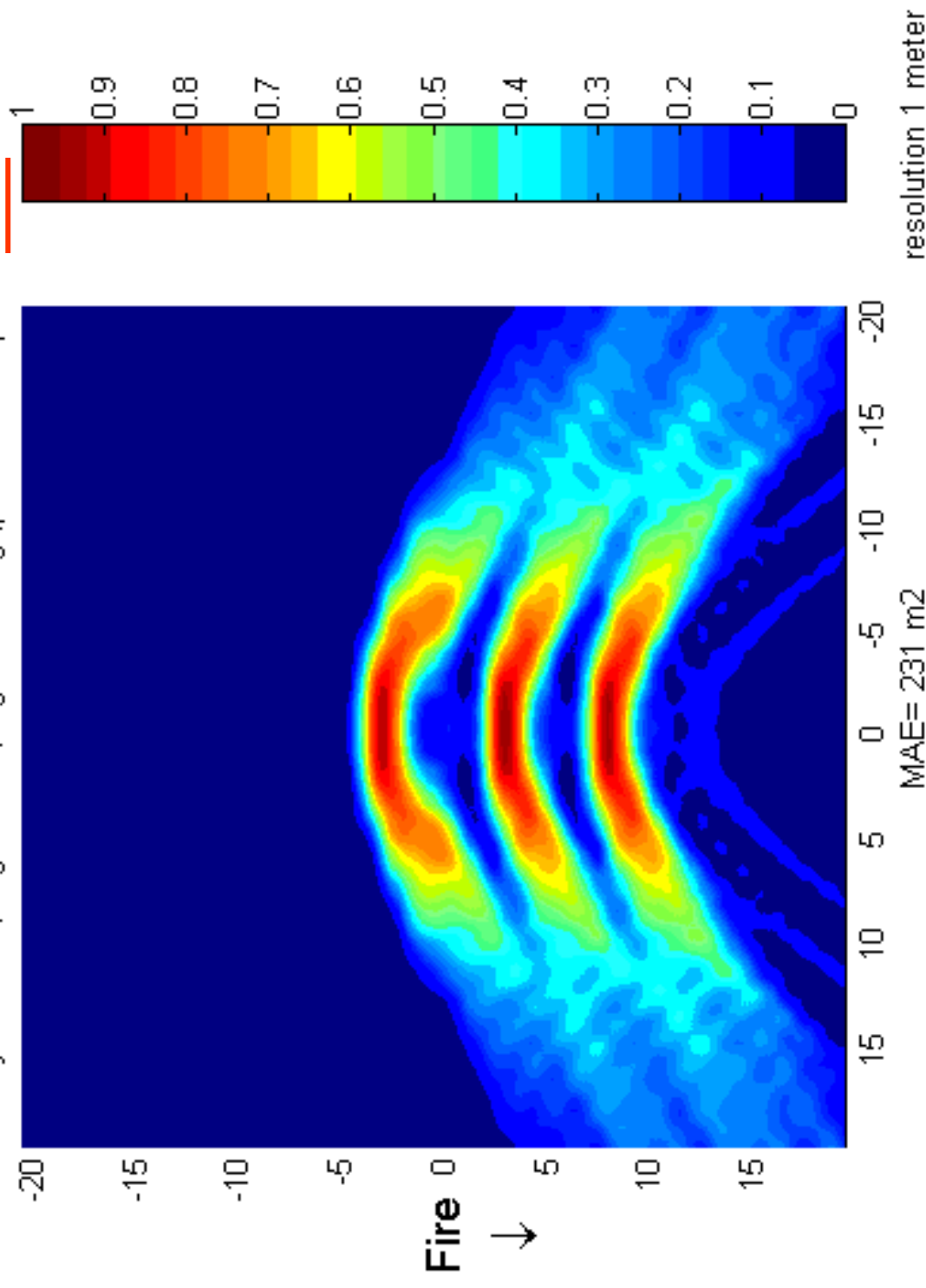
showran : velocity=855m/s,height =6m ,angle =0.3deg ,posture =six points stand



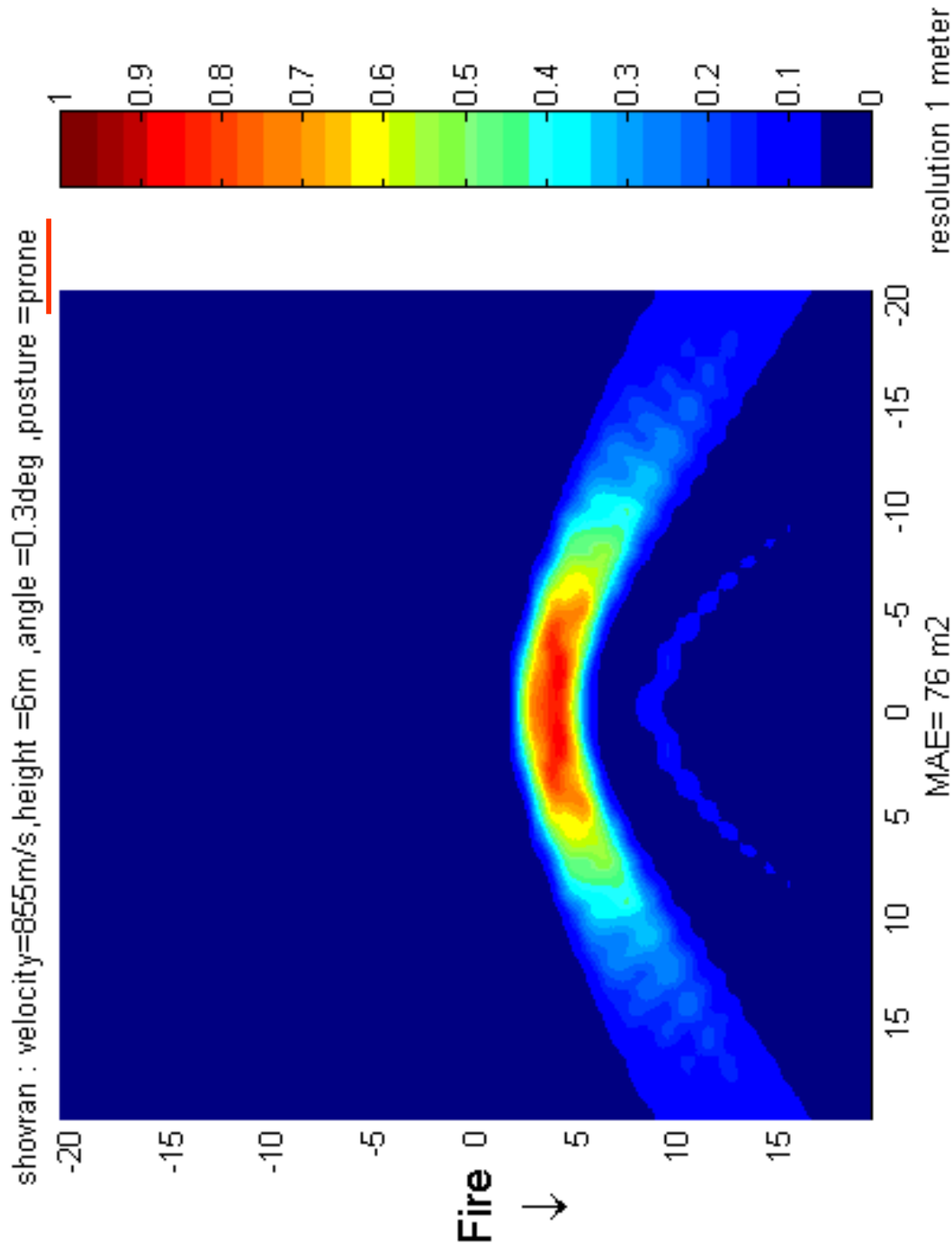


## Incapacitation Probability ( $\rho_k$ ) Map

showran : velocity=855m/s,height=6m ,angle=0.3deg ,posture=six points stand



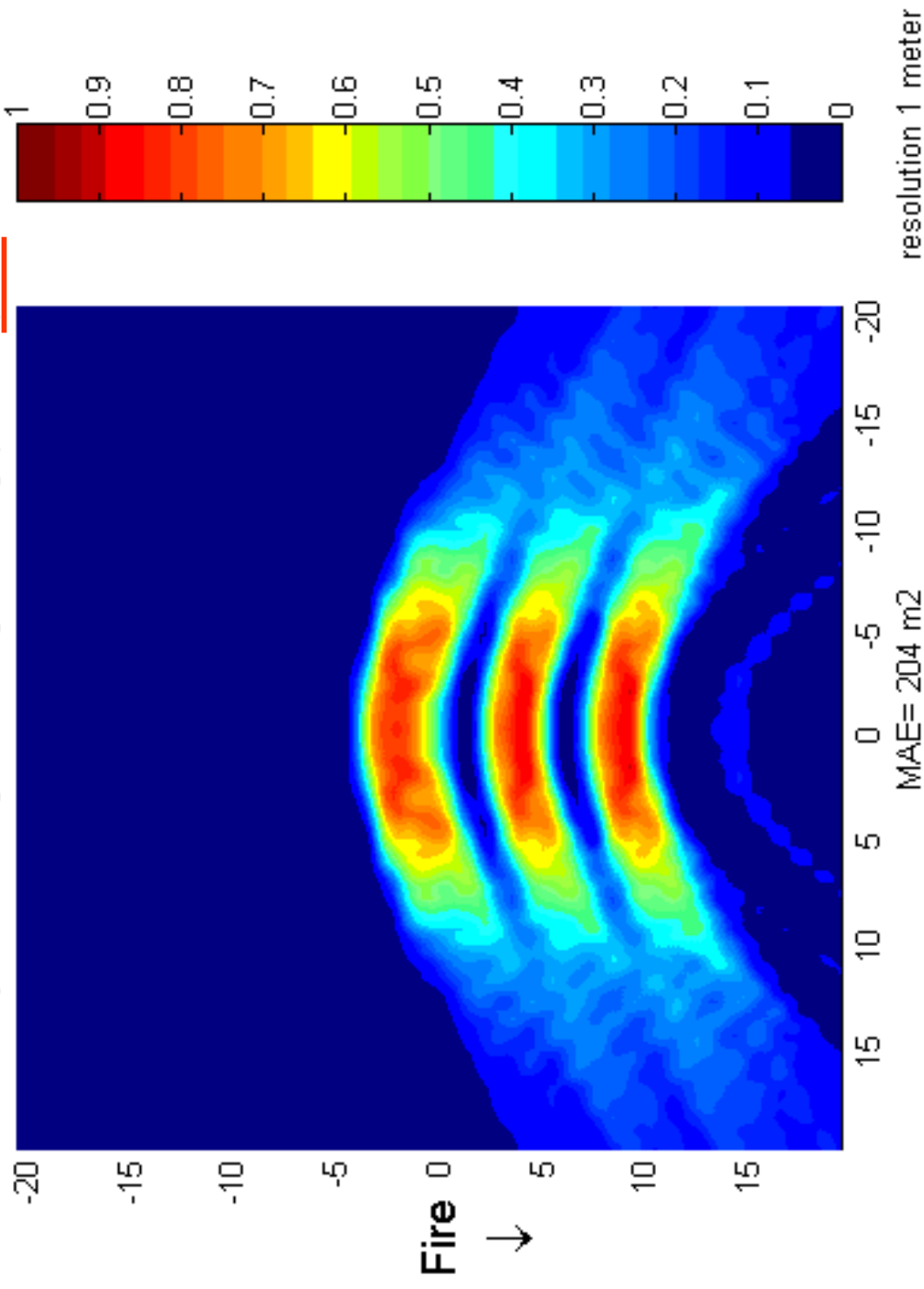
## Incapacitation Probability ( $\rho_k$ ) Map





## Incapacitation Probability ( $\rho_k$ ) Map

showran : velocity=855m/s,height=6m ,angle=0.3deg ,posture=prone

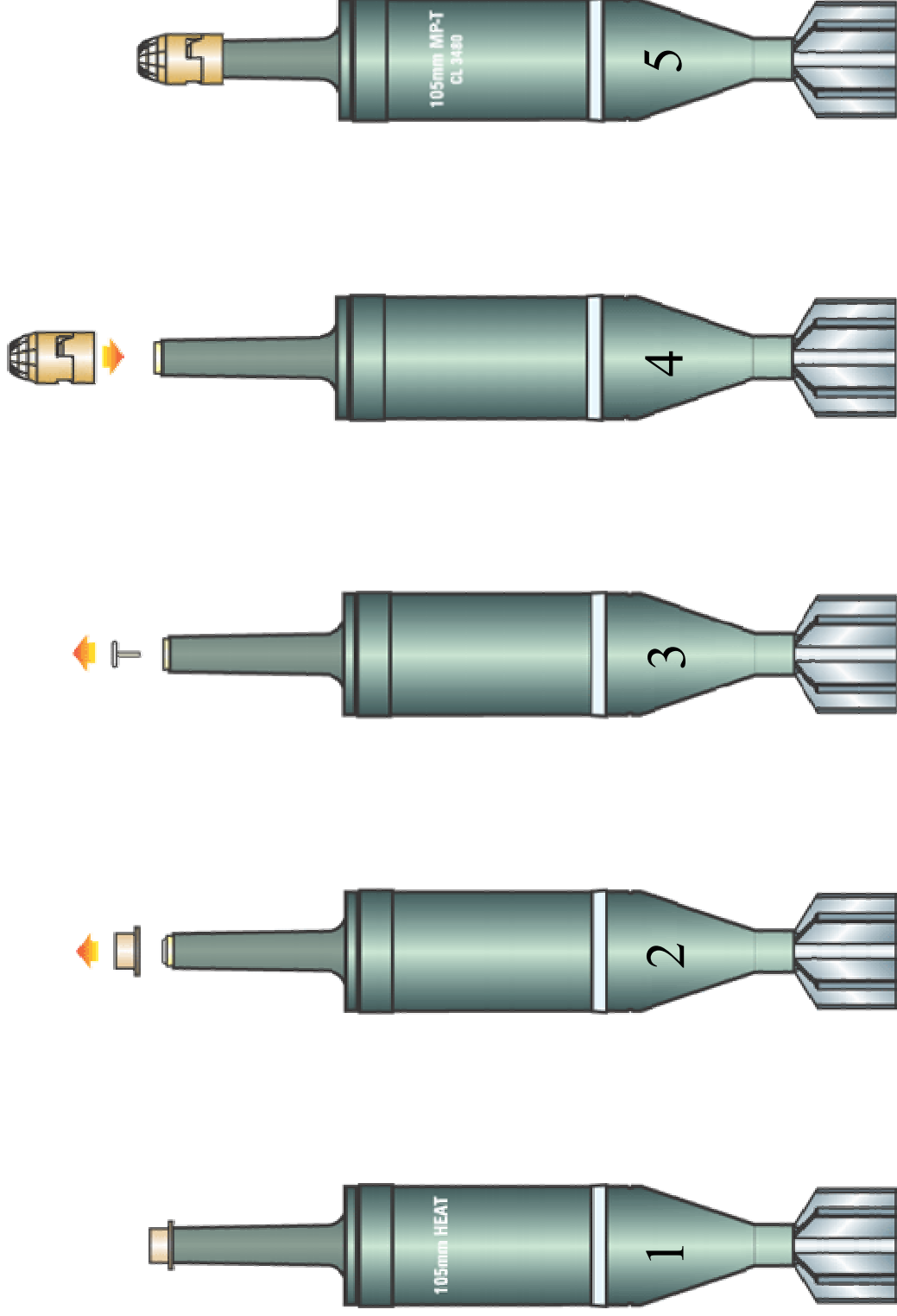




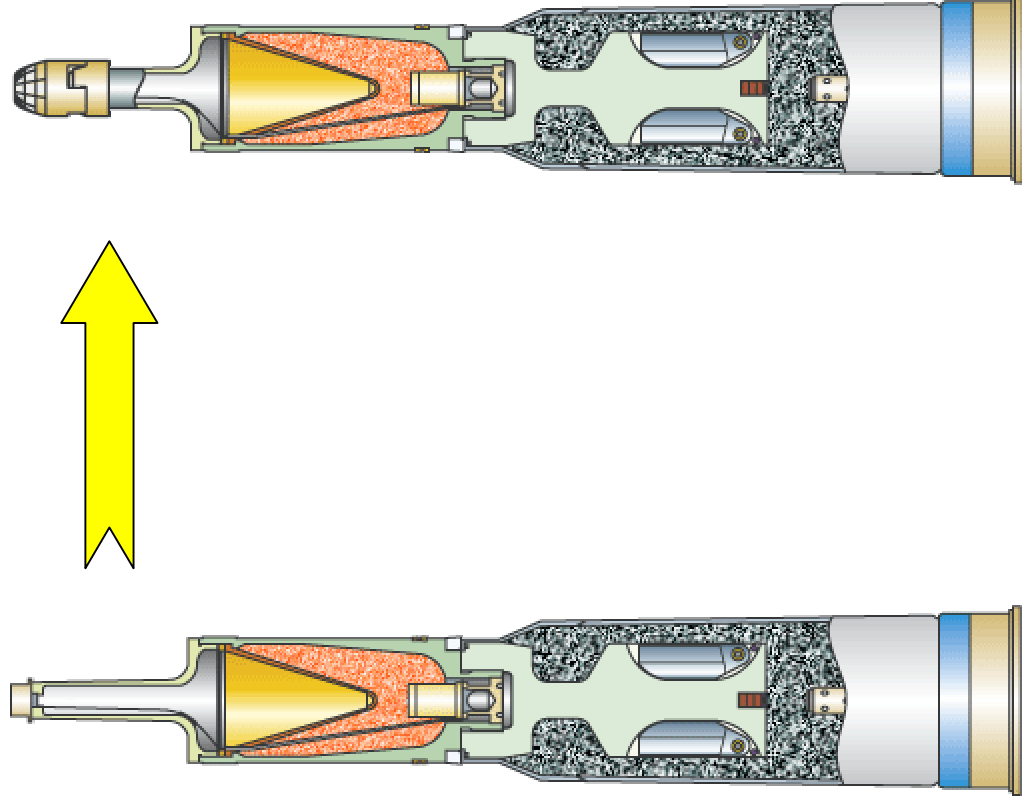
## ❖ Grazing (impact switch) Functioning test



## Conversion of M456 or IMI M152/3 to IMI M152/6 at field level



# Growth Potential – 120 mm



## CHARACTERISTICS

### Cartridge

Weight ..... 25 kg  
Length ..... 984 mm

### Projectile

Weight ..... 15 kg  
Length ..... 726 mm  
Body material ..... steel  
Explosive ..... Comp. B, 1.8 kg

### Other Components

Cartridge case ..... combustible  
Propellant ..... M30, 5.6 kg  
Primer ..... electric, M4513  
Fuze ..... dual mode, electronic time/point initiated  
base detonation (ET-PIBD)

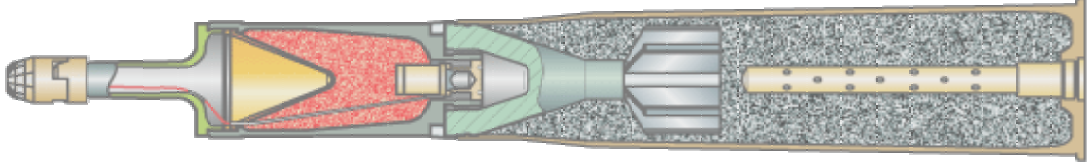
## BALLISTIC PERFORMANCE

Muzzle velocity ..... 1078 m/s  
Accuracy, typical SD ..... 0.25 mil, H and B  
Effective range ..... more than 3000 meters  
Set for time ..... projectile detonates 5 m  
(=distance) functioning ..... above ground

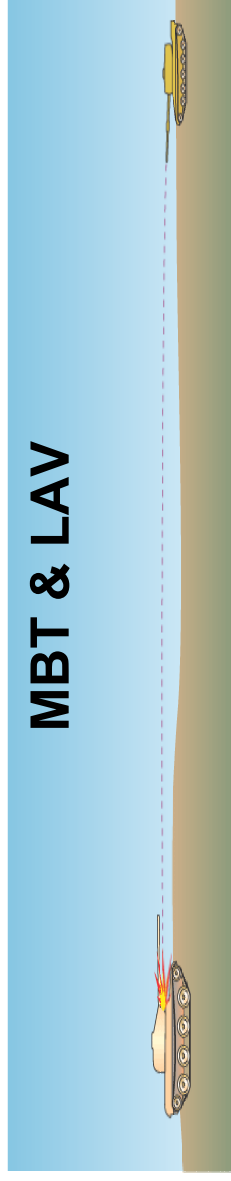
## BALLISTIC PERFORMANCE

Temp. limits, firing ..... -40 to +52°C  
Temp. limits, storage ..... -40 to +63°C  
Various tests IAW MIL-STD-810D and NATO standards

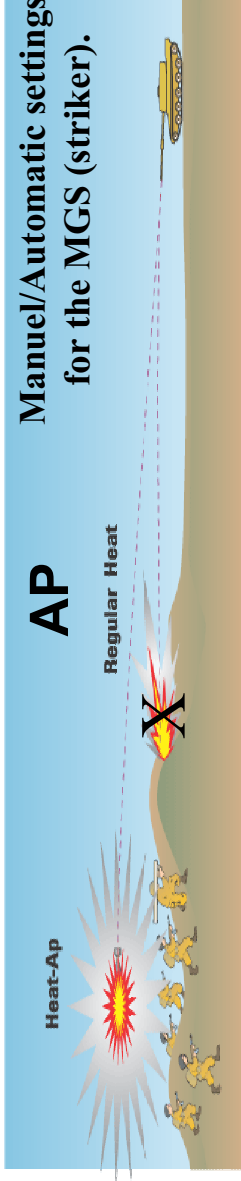
# Summary - Targets and Operating Modes



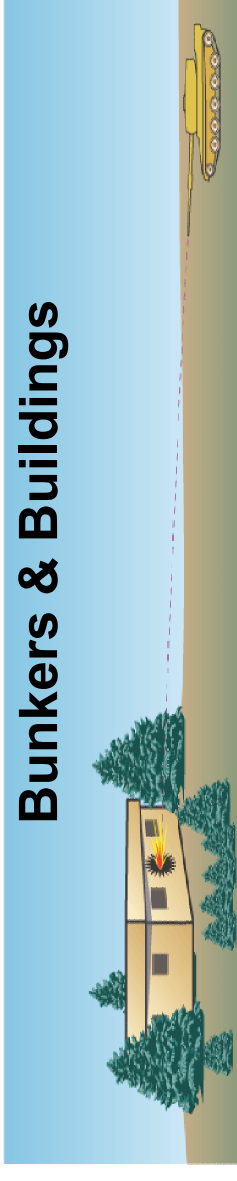
**M152/6**



**MBT & LAV**



**AP**  
Regular Heat  
Heat-Ap  
Manuel/Automatic settings for the MGS (striker).



**Bunkers & Buildings**

**Grazing (safety)**

If the projectile grazes the ground, an impact switch functions and detonates the warhead (no duds).

# Development, evaluation and lifetime prediction of medium and large caliber ammunition

Gert Scholtes, 40<sup>th</sup> GARM, April 25-28, 2005



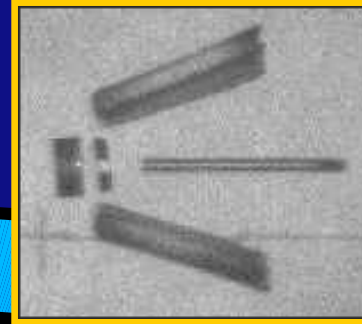
Development, evaluation and lifetime prediction of medium and large calibre ammunition

# Overview

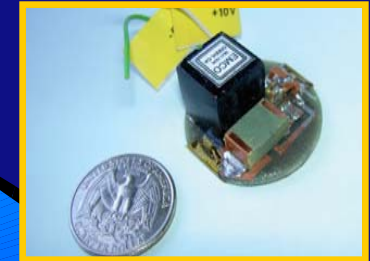
Propellant



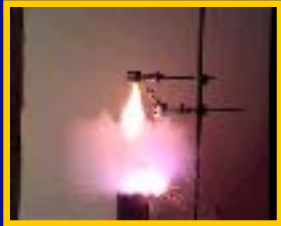
Flight



Ignition train



Ignition propellant



Lifetime prediction

Surveillance

Performance

IM Warhead



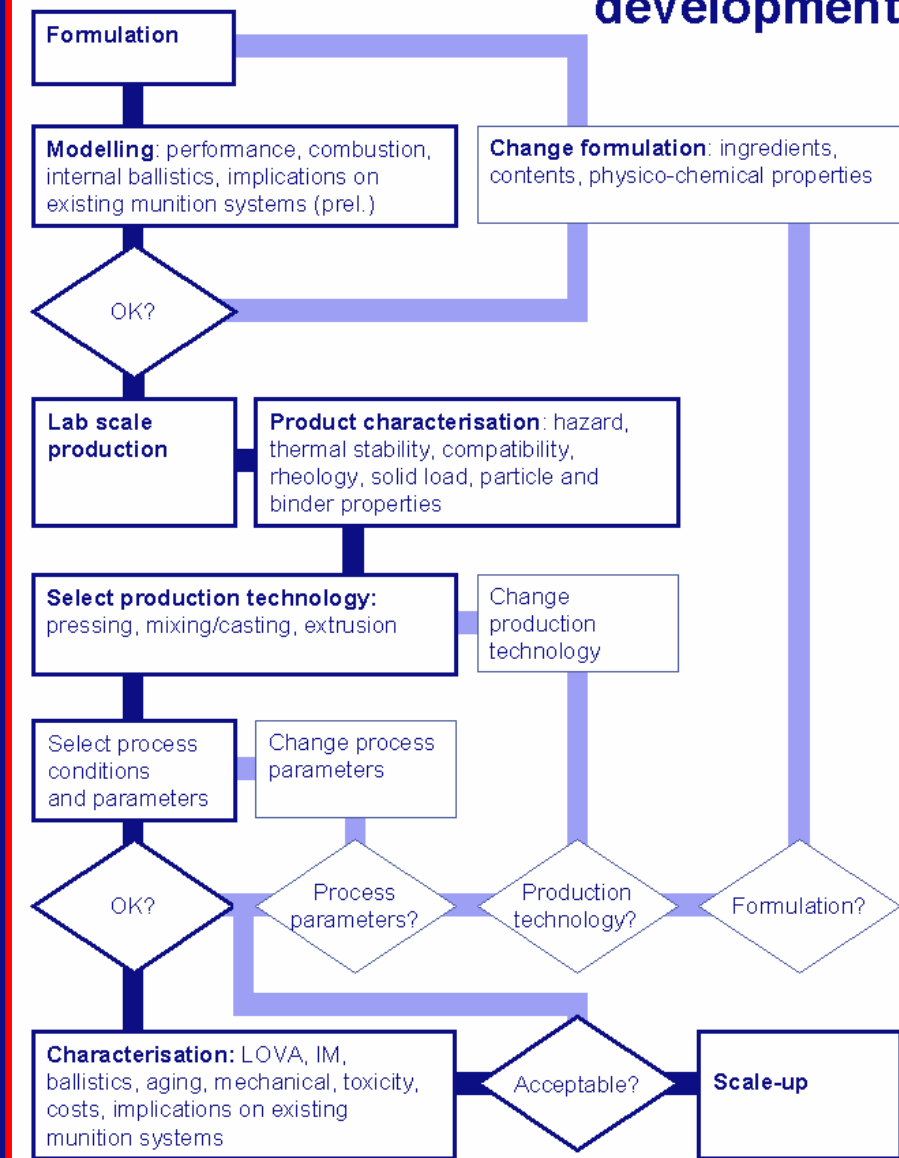
Effectiveness



Hit



## Advanced gun propellant development

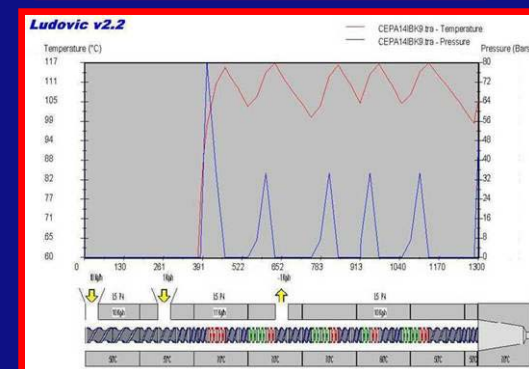
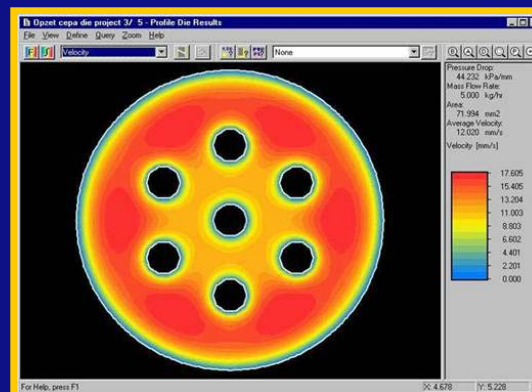
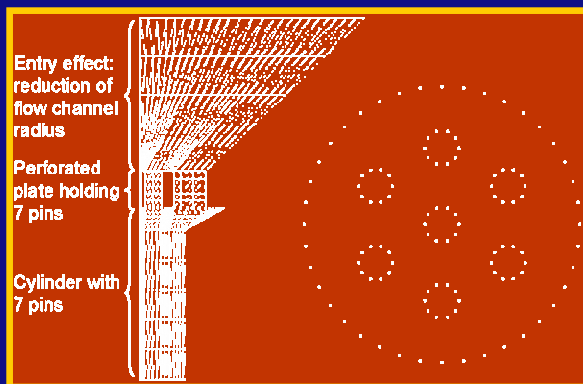
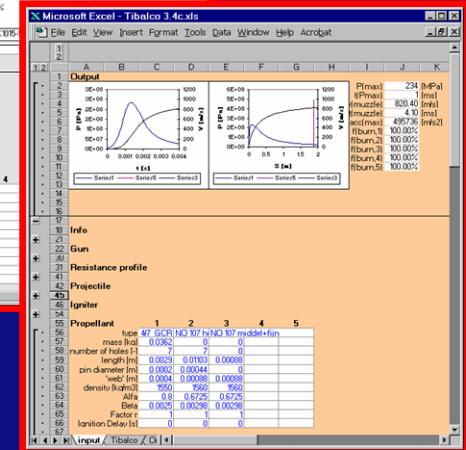
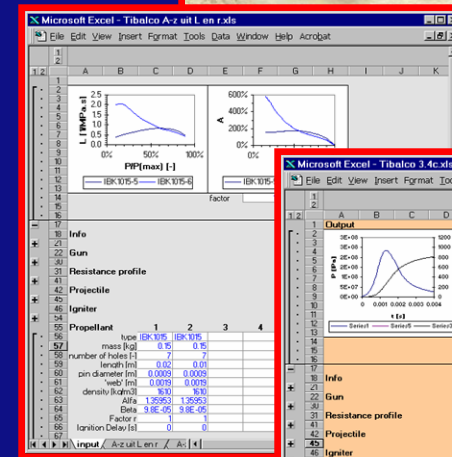
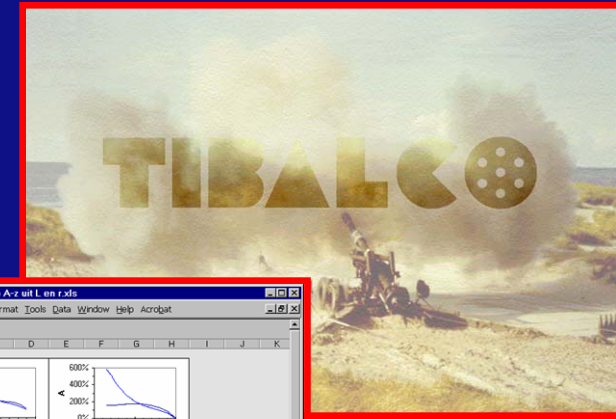


## Propellant: Capabilities

- Modeling & simulation
  - Thermodynamics
  - Processing
  - Internal ballistics
- Lab-scale production
  - Up to ~ 1 kg (analyses)
- 'Small scale' production
  - Up to ~ 300 kg
- Performance testing
  - Closed & vented bombs
  - Test guns
  - Thermal, IM & safety properties

# Propellant: Modeling & simulation

- Thermodynamics
  - NASA-Lewis, Blake, ICT-code
- Internal ballistics
  - TIBALCO (TNO Internal BALListic Code)
- Processing
  - Rheology
  - Extrusion & shaping processes



# Propellant: Processing



*45 mm twin-screw extruder*

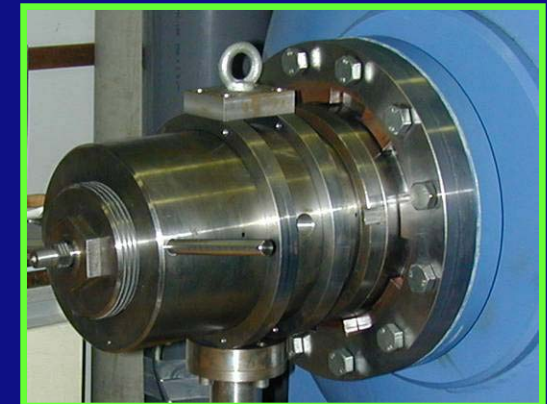
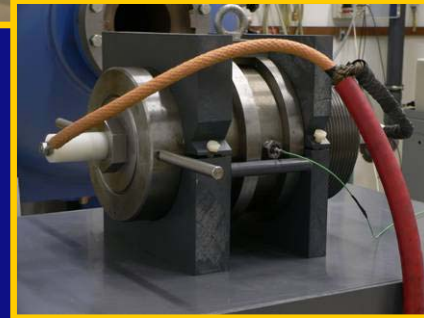


# Propellant: Test facilities

- Closed Vessels
  - 43.5 cc / 130 cc LPCV (20 MPa)
  - 25 - 700 cc CV (150 – 500 MPa)
  - 400 cc HPCV (1000 MPa)
- Erosivity & burning interruption tests
  - 130 cc – 20 MPa
  - 500 cc – 150 MPa
- Plasma ignition
- Instrumented guns
  - .50 gun
  - 29-mm / 50-mm / 78-mm accelerator



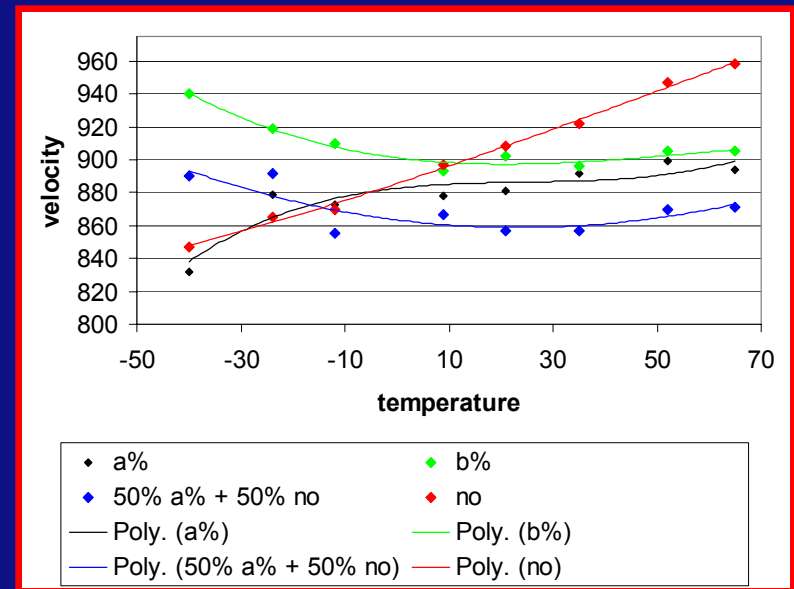
*CV's  
(25 – 700cc)*



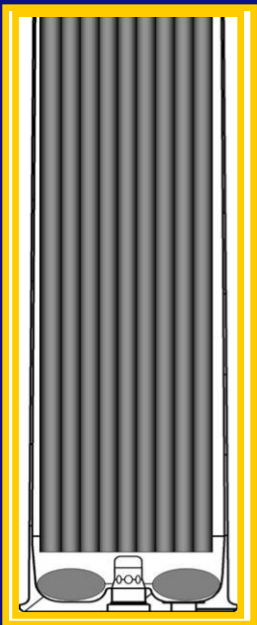
*Vented HPCV and  
catch tank*

# Propellant: Examples of R&D projects

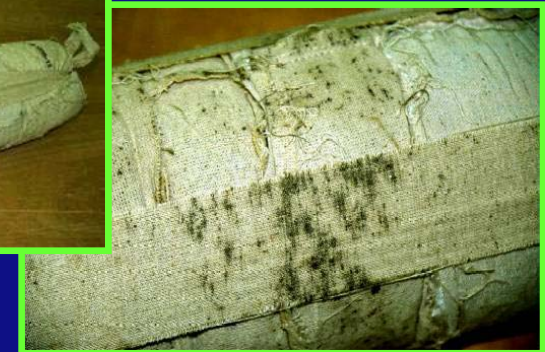
- Propelling charge development
- Temperature independent propellant
- Barrel erosion
- Ageing & lifetime assessment



*Stick propelling charges for excellent ignition behaviour*



*Proven temperature independency*



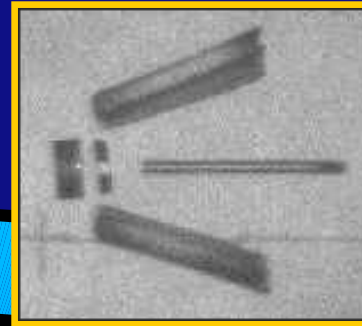
*Burning properties and mechanical integrity of aged propellants*

# Overview

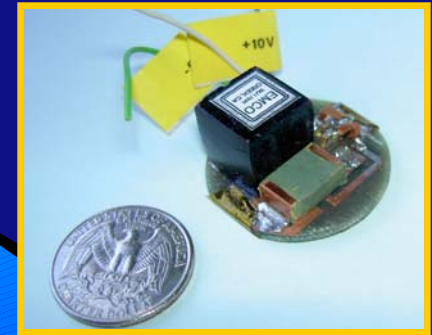
Propellant



Flight



Ignition train



Ignition propellant



Lifetime prediction

Surveillance

Performance

IM Warhead



Effectiveness

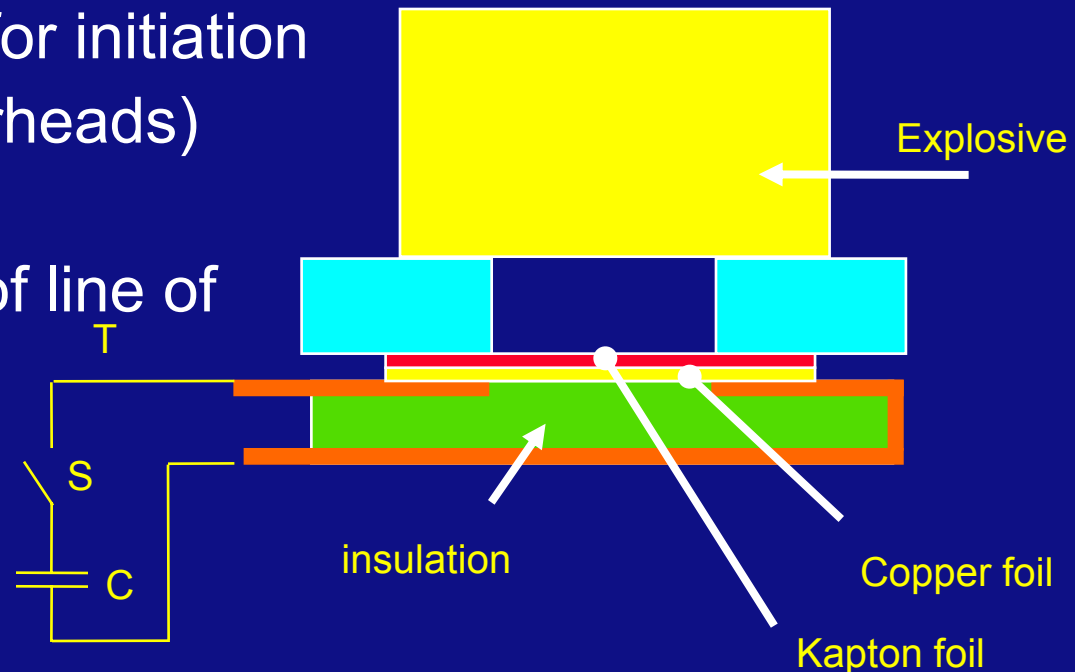
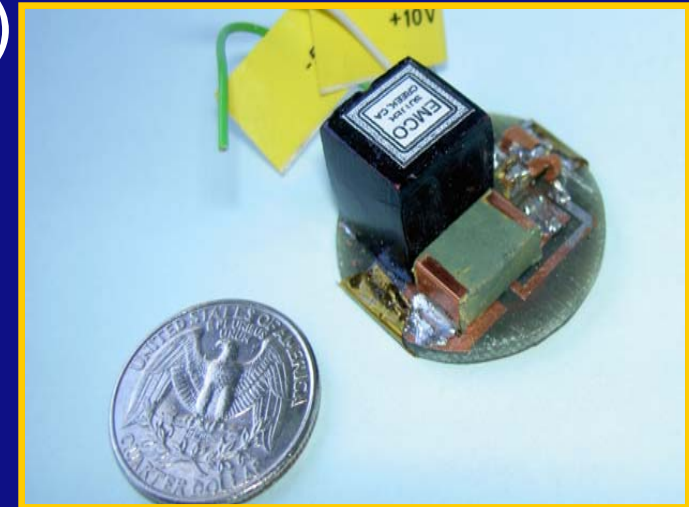


Hit



# MEMs Exploding Foil Initiator (EFI)

- Intrinsic safe
  - No primary explosives
  - Not sensitive to EM fields
- Precision timing for initiation (e.g. aimable warheads)
- Very reliable
- No need for out-of line of charge

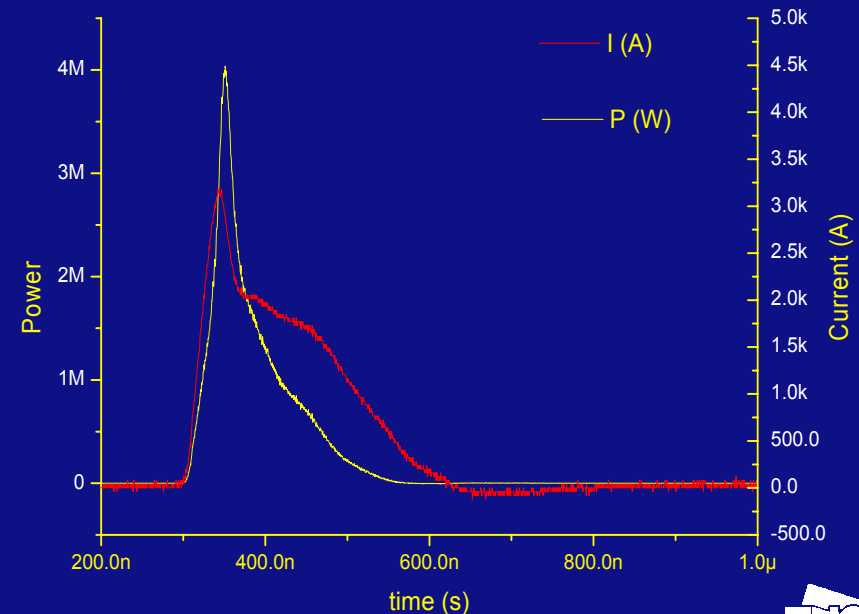


# MEMs EFI: What you need

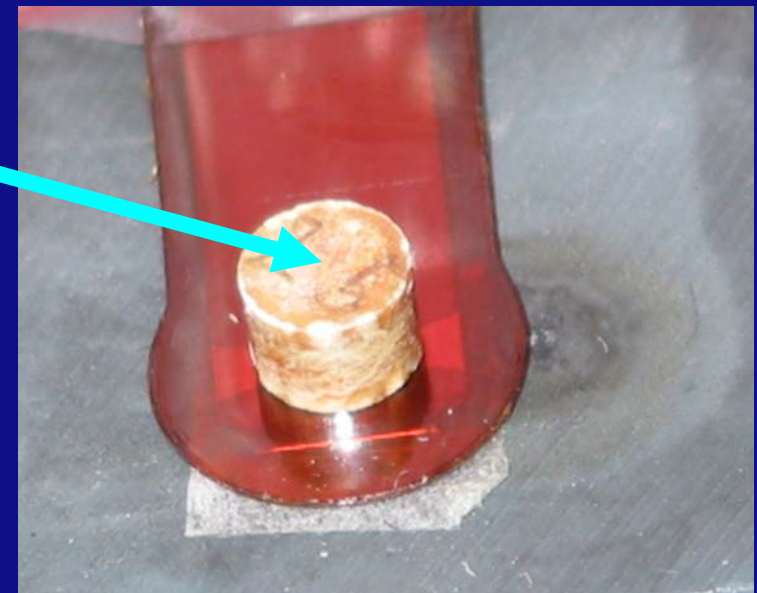
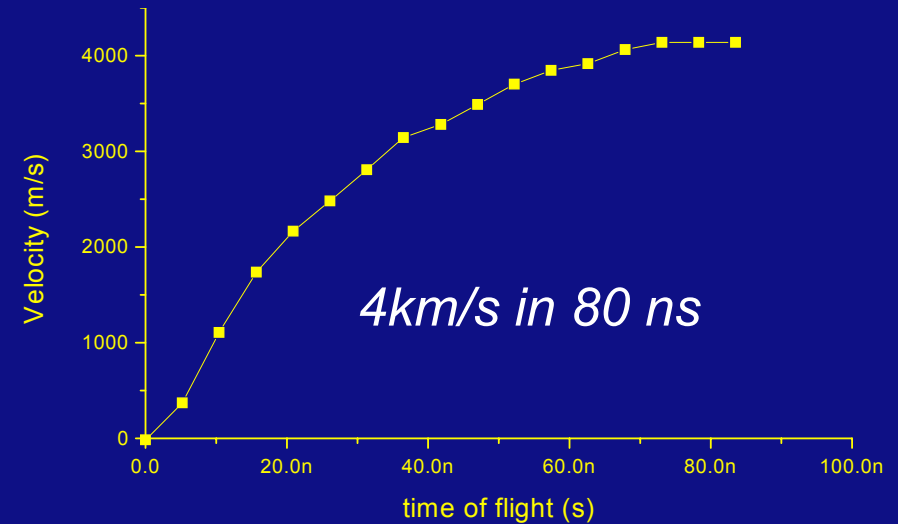
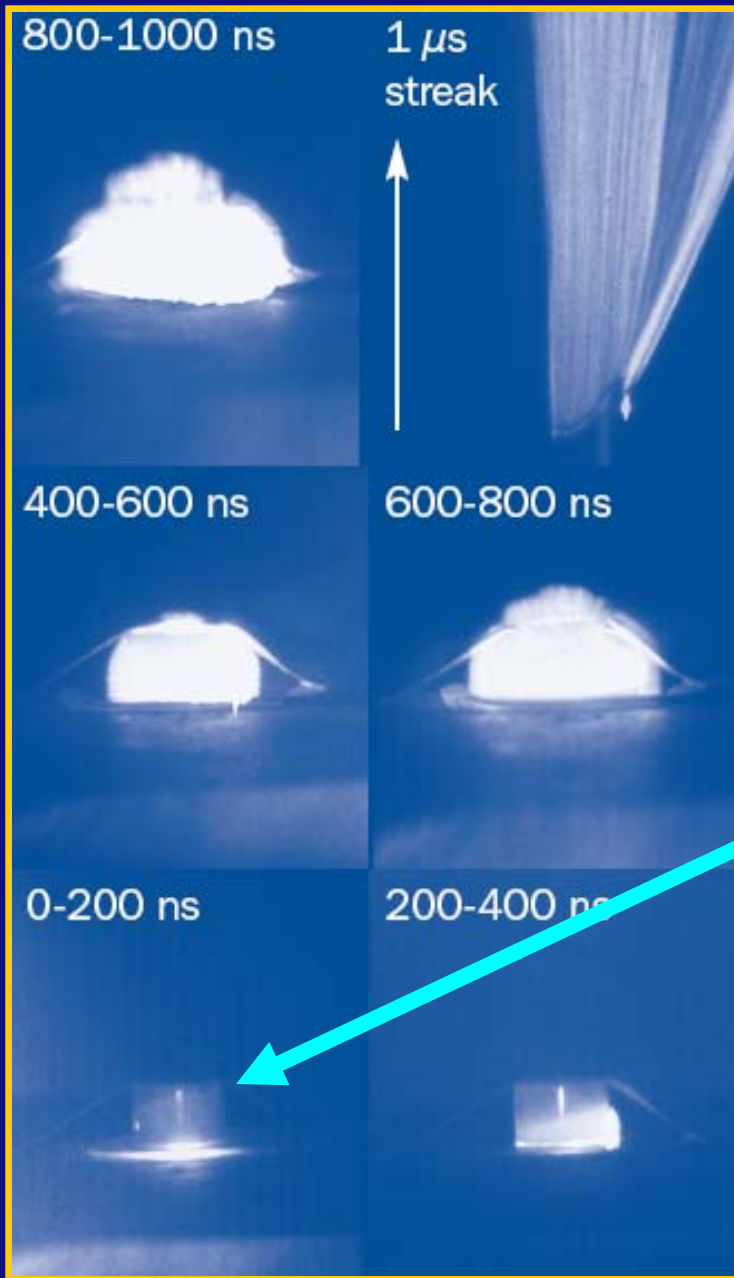
- Proper circuit with COTS components
  - Small high voltage power supply (several kV and kA)
  - Solid state Switching device
- Appropriate dimensions and properties of:
  - Exploding foil
  - Flyer plate
  - Strip-line
  - Barrel
- Pressed HNS-IV crystals at the right density



Performance of an optimised EFI-circuit



# Ignition train: MEMs EFI

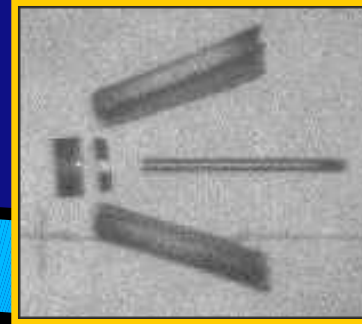


# Overview

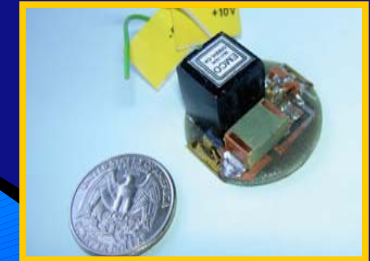
Propellant



Flight



Ignition train



Ignition propellant



Lifetime prediction

Surveillance

Performance

IM Warhead



Effectiveness

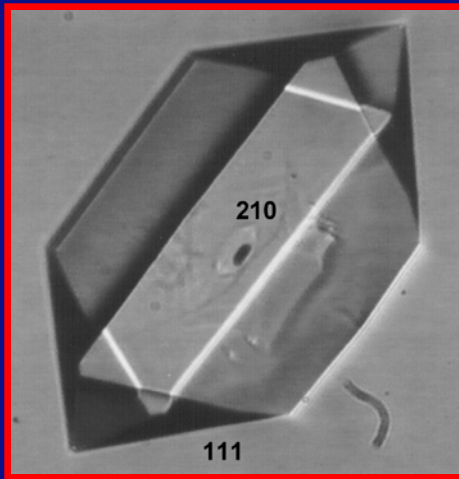


Hit



# Warhead: recrystallisation to obtain the next generation of explosives

RS-RDX



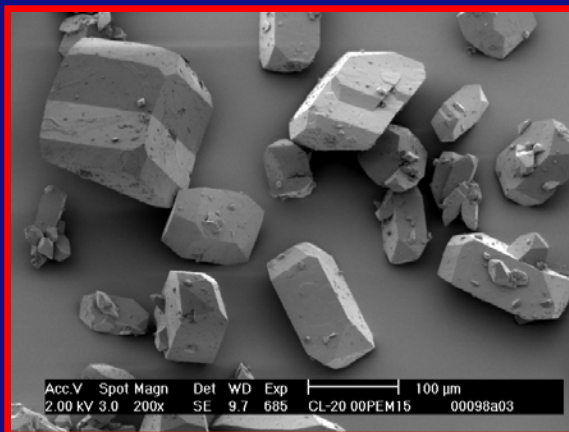
HNF



Insensitive crystals for rocket propellants

Insensitive crystals for HE Warheads

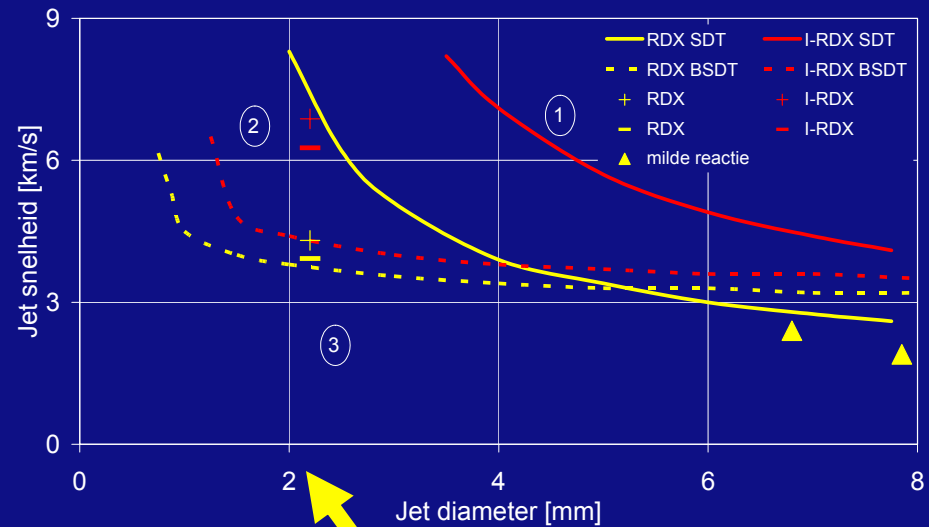
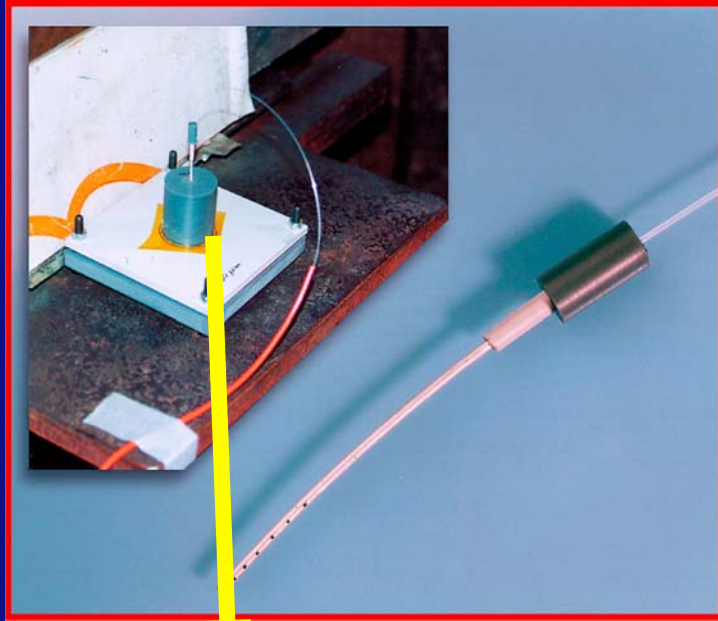
CL-20



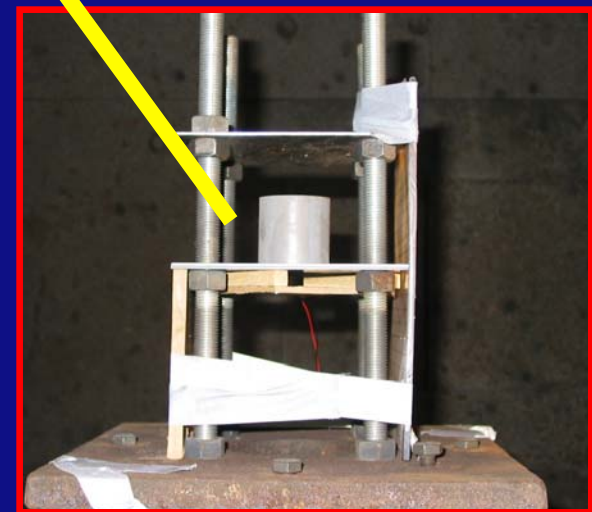
HNS-IV

Insensitive crystals for Booster Explosives

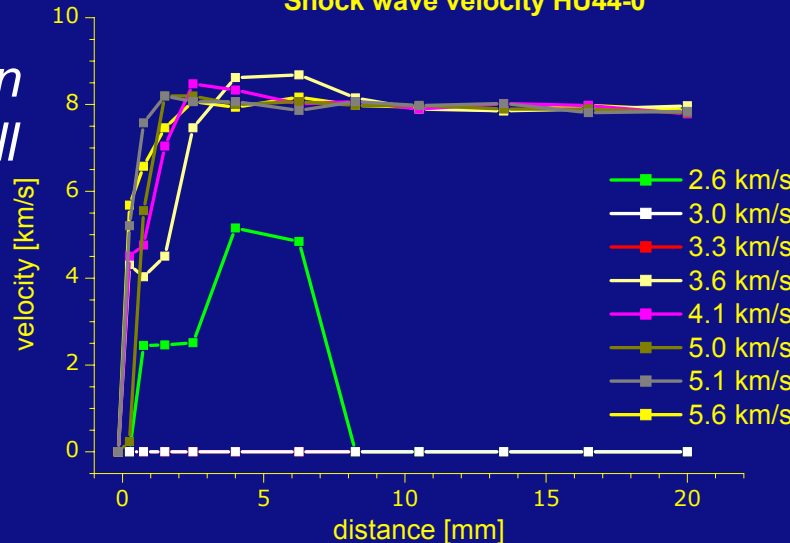
# Warhead: characterisation of explosives



*Shaped charge testing and simulation (PBXN109)*

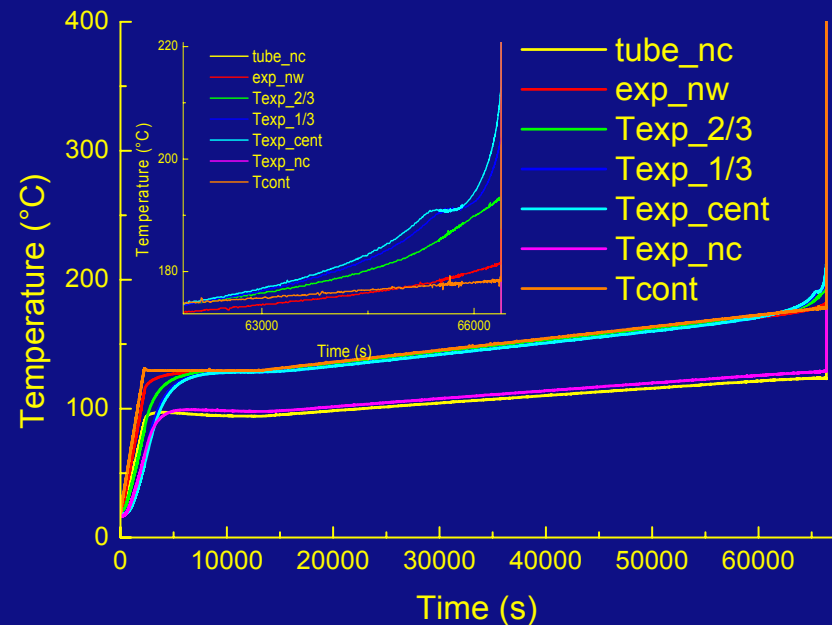


Shock wave velocity HU44-0



*Shock initiation testing of small samples*

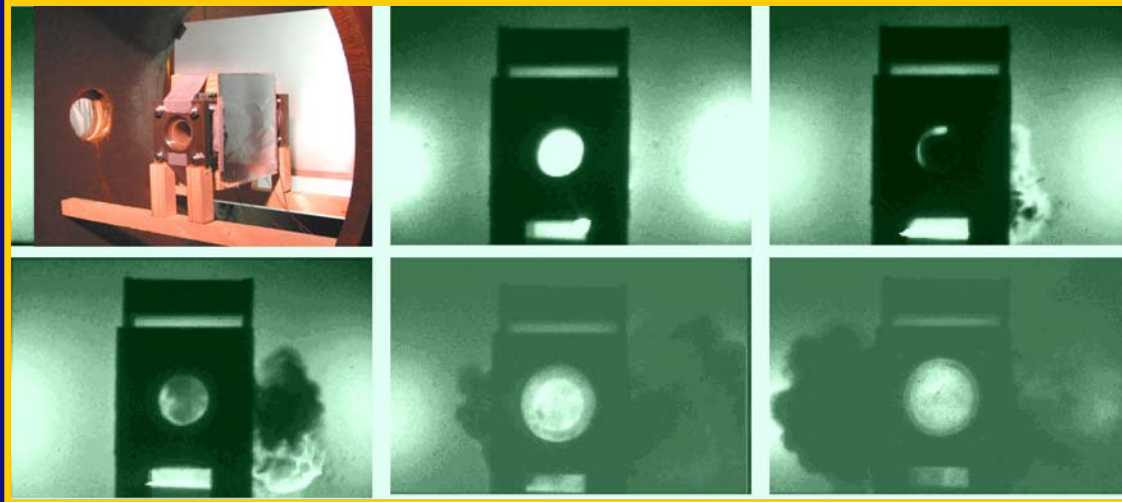
# Warhead: Understanding the behaviour of explosives and IM



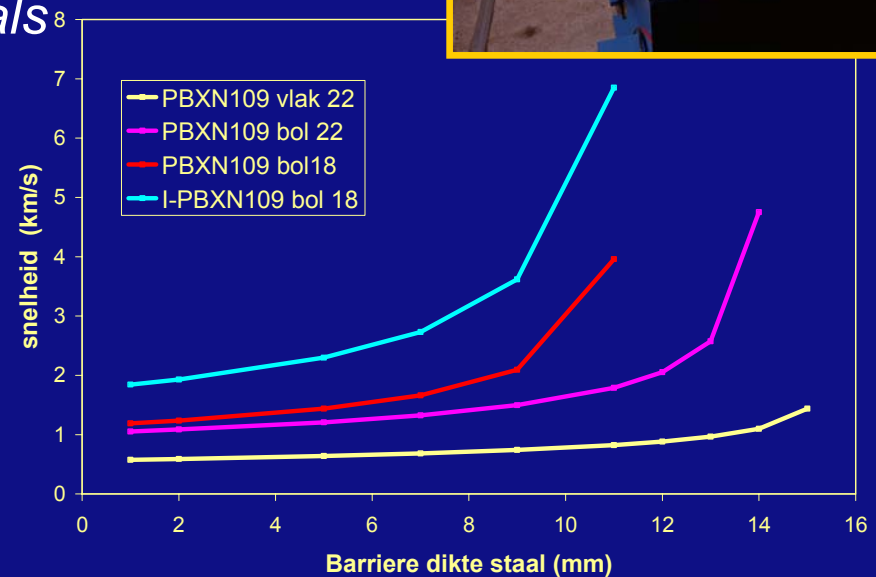
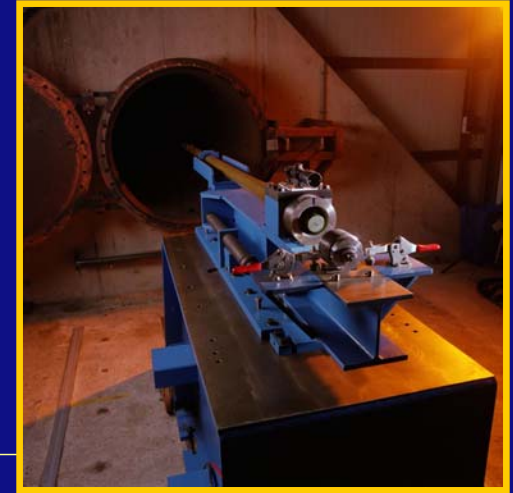
*Cook-off testing  
and Simulation*

# Warhead: Understanding the behaviour of explosives and IM

*Bullet/Fragment testing and simulation*



*The responses of a confined materials after the impact of a fragment.*

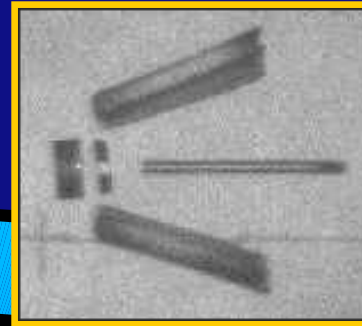


# Overview

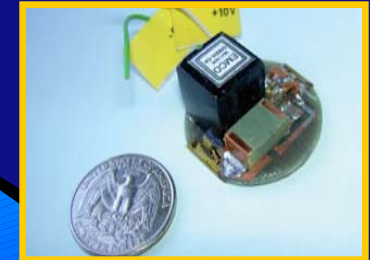
Propellant



Flight



Ignition train



Ignition propellant



Lifetime prediction

Surveillance

Performance

IM Warhead



Effectiveness

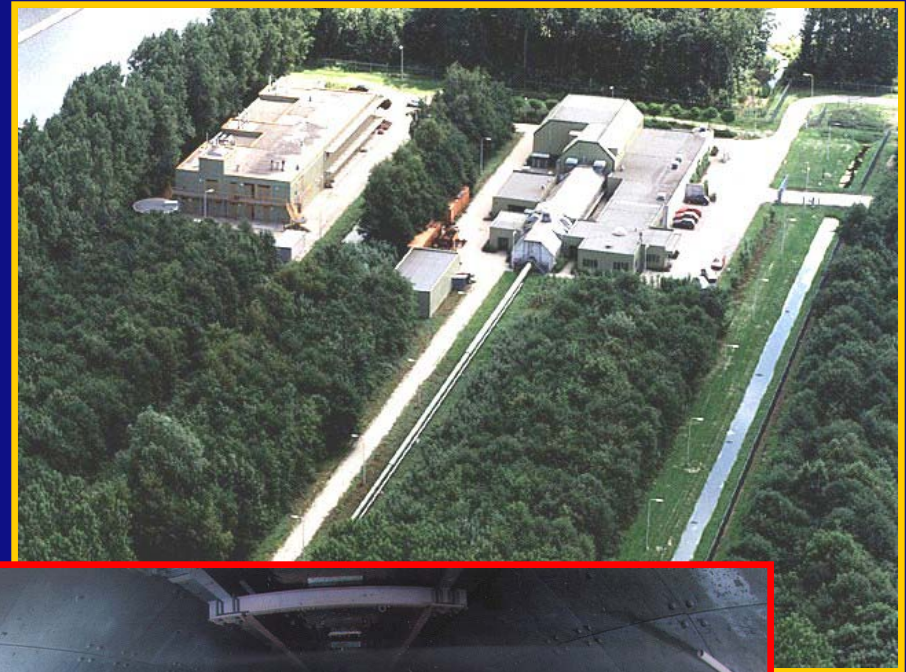
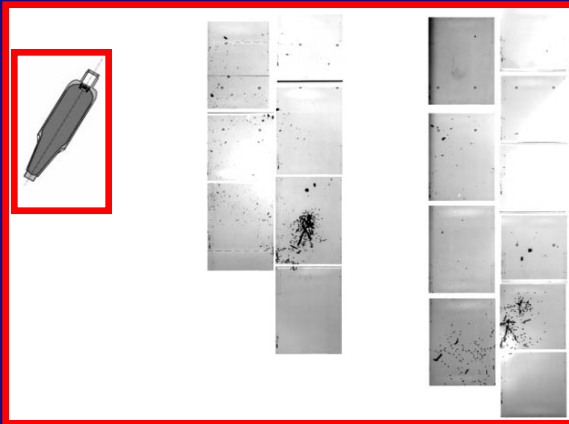


Hit



# Effectiveness: Fragmenting ammunition testing

- 60 m range for HE  $\leq 76$  mm
- 200 m range for KE  $\leq 40$  mm
- Bunker for  $\leq 25$  kg TNT

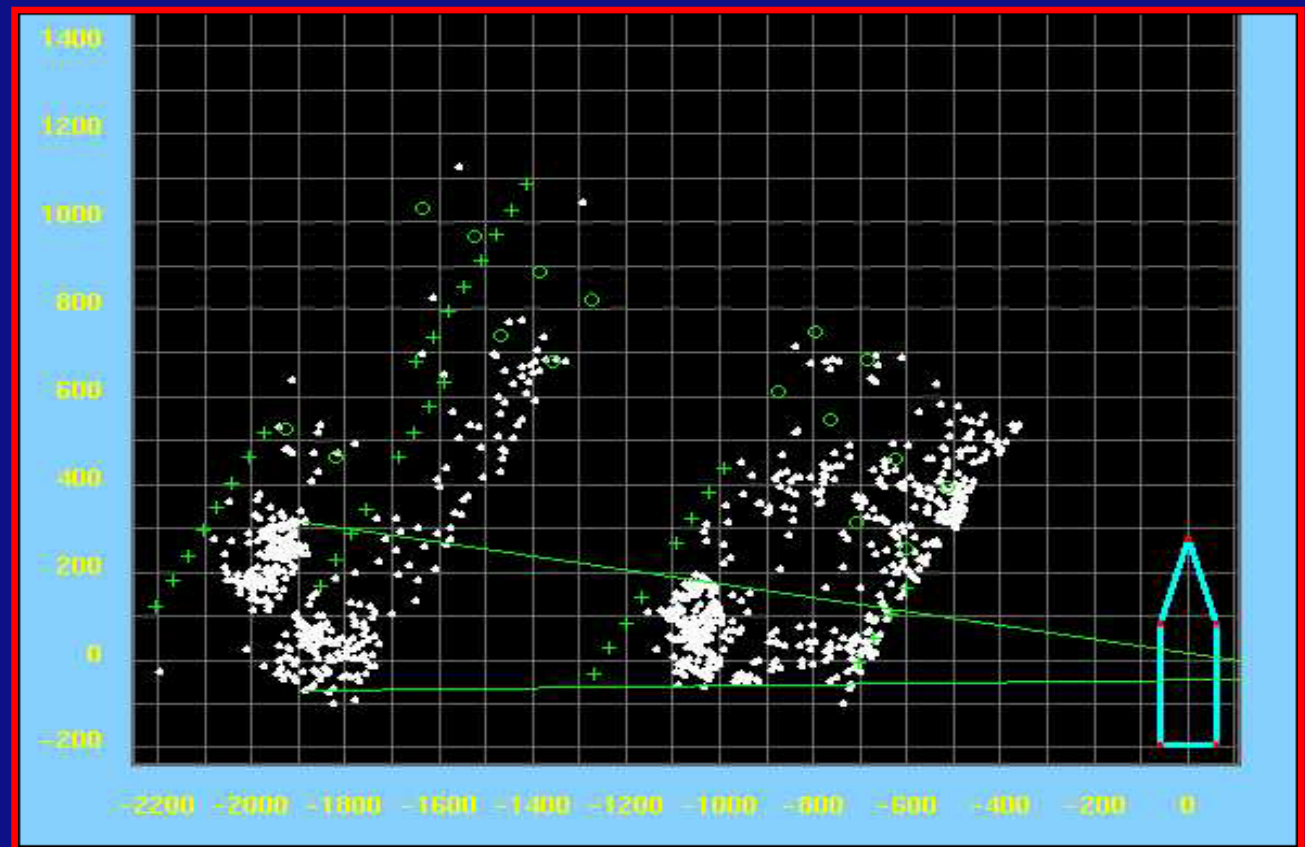


- Fragment cloud analysis method
  - Rotational symmetry
  - Cylinder with windows
  - Cardboard soft recovery
  - X-ray shadowgraphs
  - Image processing

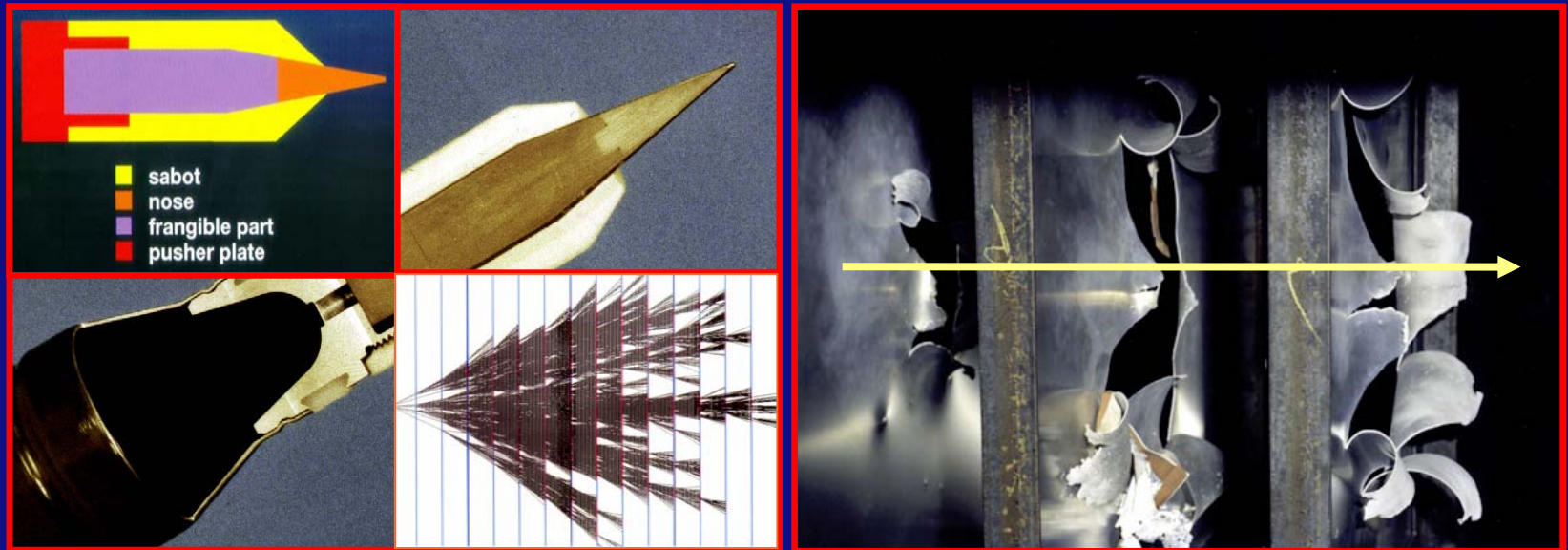


# Effectiveness: Fragmenting ammunition testing

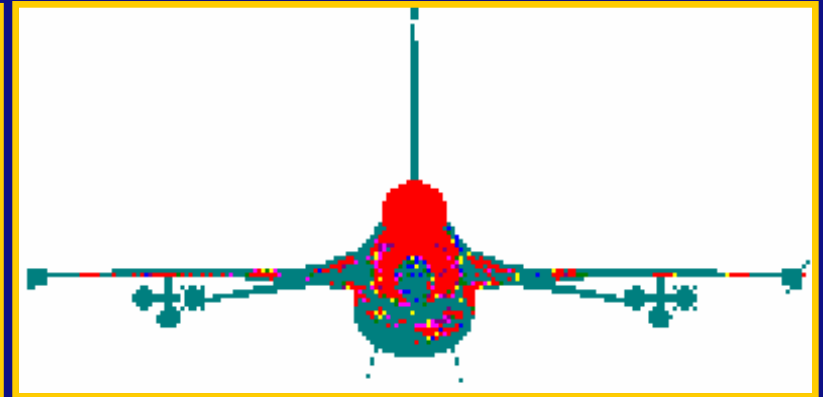
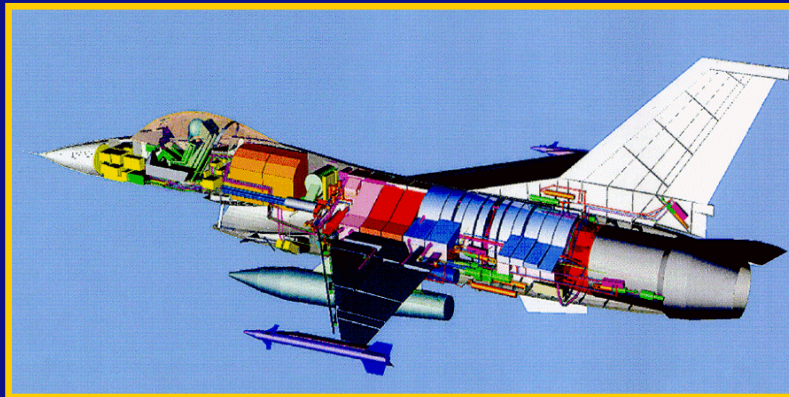
- Fragment distribution
  - Spatial
  - Velocity
  - Mass
  - Energy



# Effectiveness: Munition Lethality/Platform Vulnerability



*Terminal ballistics experiments & simulations*



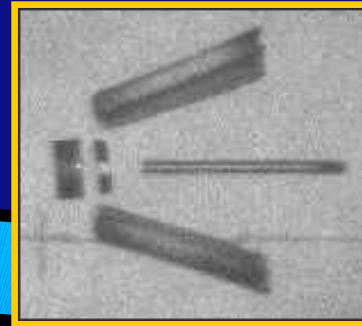
*Lethality / vulnerability simulations*

# Overview

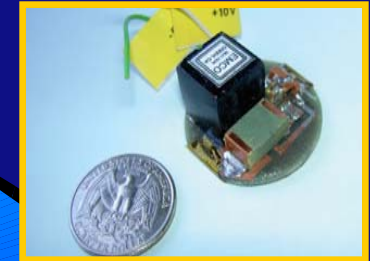
Propellant



Flight



Ignition train



Ignition propellant



Lifetime prediction

Surveillance

Performance

IM Warhead



Effectiveness

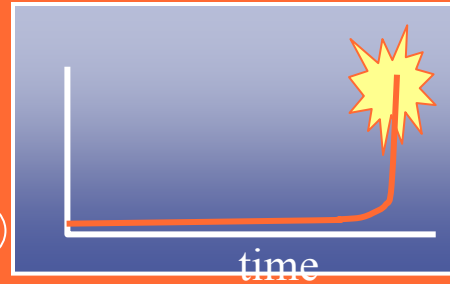


Hit



# Lifetime prediction: How to solve the safety problem?

What's the safety?



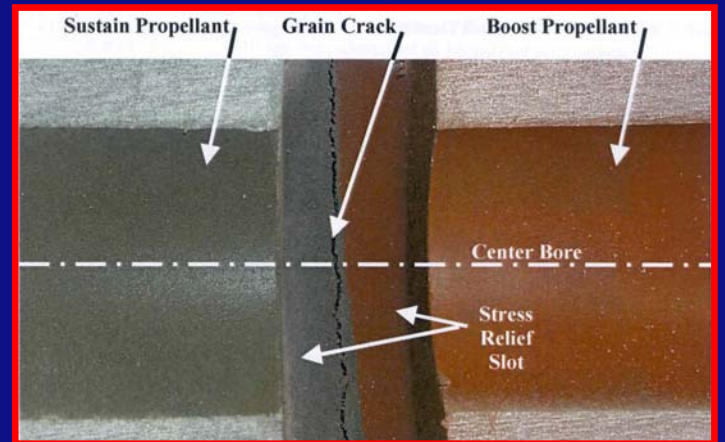
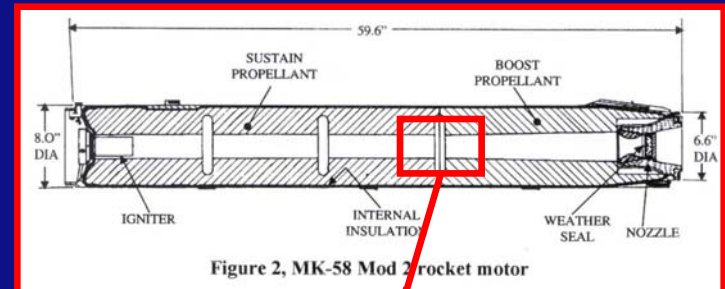
*Accident with propelling charges*

# Lifetime prediction: Ageing of missile

## US AIM-7 Sparrow incidents (1997 & 1999)

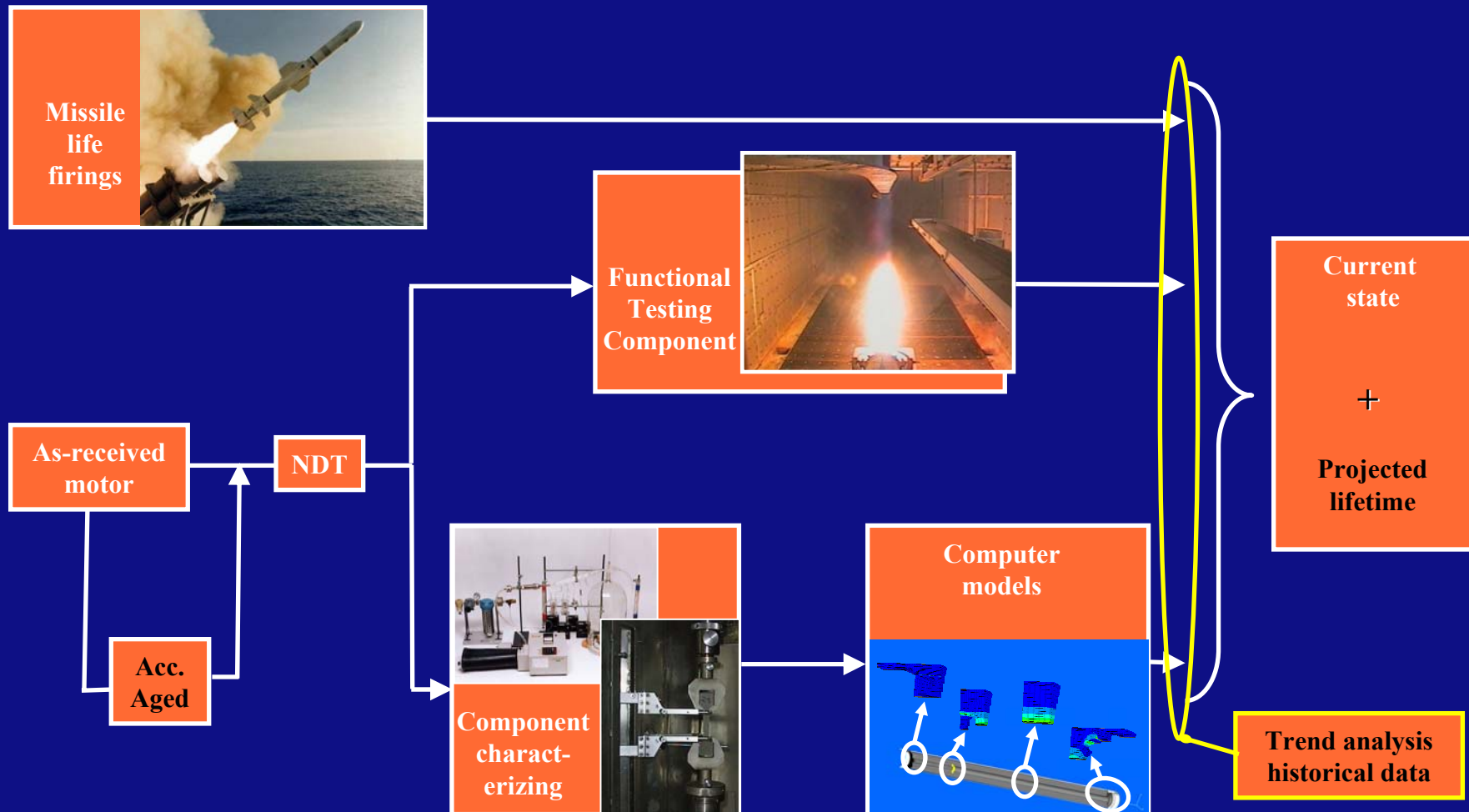


## US MK-58 Mod 2 motor investigation

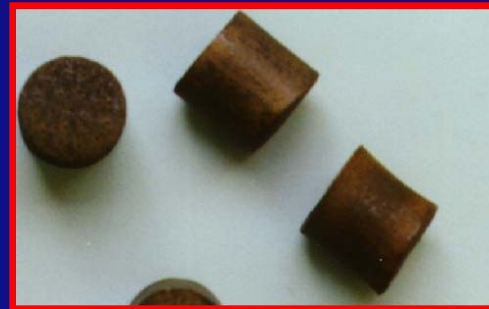


Source: paper P. Huisveld AVT-RTO-089, 2002 Aalborg

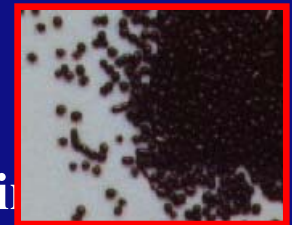
# Lifetime prediction: Element “toolbox” for missiles



# Surveillance of gun propellants



**Range of 5 sample vessels covers the whole range of propellant grains**

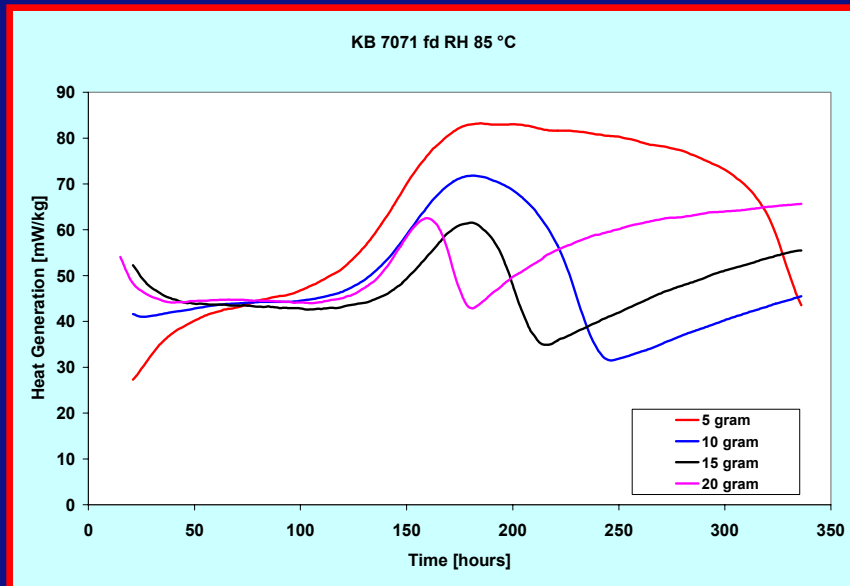


**No pre-treatment of grain necessary**



# Surveillance of gun propellants

- Heat flow Calorimetry (HFC) with full size grains
- Heat generation in time as function of loading density of vessel
- →Munition like testing



# Lifetime production and surveillance: Products

- Lifetime studies (Toolbox)
- Surveillance methodology for gun propellants (realistic comparison to ammunition situation, including
  - Equipment
  - Tailor made training programme
  - Tailor made munition management system
  - Guarantee and spare parts

# Summary

- TNO Defence, security and safety is an independent organisation and a strategic partner for the Dutch Ministry of defence
- We also use our accumulated expertise for foreign governments and for defence related industries.
- R&D → development → prototyping → pre-production → production → in service, of munition: TNO has the expertise for Effective and Insensitive Munitions development.
- But also the expertise for lifetime predictions and surveillance of propellants.
- Combination of experimental facilities, theoretical knowledge/expertise and model/computer codes makes TNO a qualified partner for your future munitions development.



## **LINE OF SIGHT/BEYOND LINE OF SIGHT (LOS/BLOS) ADVANCED TECHNOLOGY DEMONSTRATOR (ATD)**

**BRIEFING FOR THE GUNS, AMMUNITION, ROCKETS &  
MISSILES SYMPOSIUM - 25-29 APRIL 2005**

*Providing America Advanced Armaments for Peace and War*



**DAVID C. SMITH, P.E.  
ANTHONY J. CANNONE  
LOS/BLOS ARMAMENT TEAM**



# LIGHTWEIGHT 120 MM GUN (LW120) LOS/BLOS ATD



ISO 9001 Certified  
FS15149

- **OVERVIEW OF LOS/BLOS ATD GUN**
  - DESIGN CONCEPT
  - REQUIREMENTS
- **OVERVIEW OF TEST STATUS TO DATE**
  - TEST RESULTS PHASE 1
  - TEST RESULTS PHASE 2
  - TEST RESULTS PHASE 3 (PRELIMINARY TEST DATA)
  - IN HOUSE TESTING
- **PATH FORWARD**
- **ACCOMPLISHMENTS**



# LOS/BLOS ATD GUN OVERVIEW



ISO 9001 Certified  
FS15149

- **GOAL: DEVELOP A LIGHTWEIGHT 120MM GUN FOR USE ON A 20 TON VEHICLE**
  - **WEIGHT: < 4,400 POUNDS**
  - **RECOIL IMPULSE: < 5,300 POUND-SECONDS**
  - **RECOIL LENGTH 25 INCHES**
  - **SPACE CLAIM LIMITS OF MCS CONCEPT VEHICLE**
- **STATUS & ONGOING ACTIVITIES**
  - **VEHICLE DYNAMIC RESPONSE DEMONSTRATOR (VDRD) GUN DEVELOPED AND COMPLETED TESTING IN FEBRUARY 2004**
  - **LINE OF SIGHT/BEYOND LINE OF SIGHT (LOS/BLOS) ADVANCED TECHNOLOGY DEMONSTRATOR (ATD) PROGRAM BUILT AND TESTED 3 VERSIONS OF THE LIGHTWEIGHT 120MM GUN FROM NOVEMBER - MARCH 2005**
  - **KEY TECHNOLOGIES CONTINUE MATURING IN NEW PROGRAM**

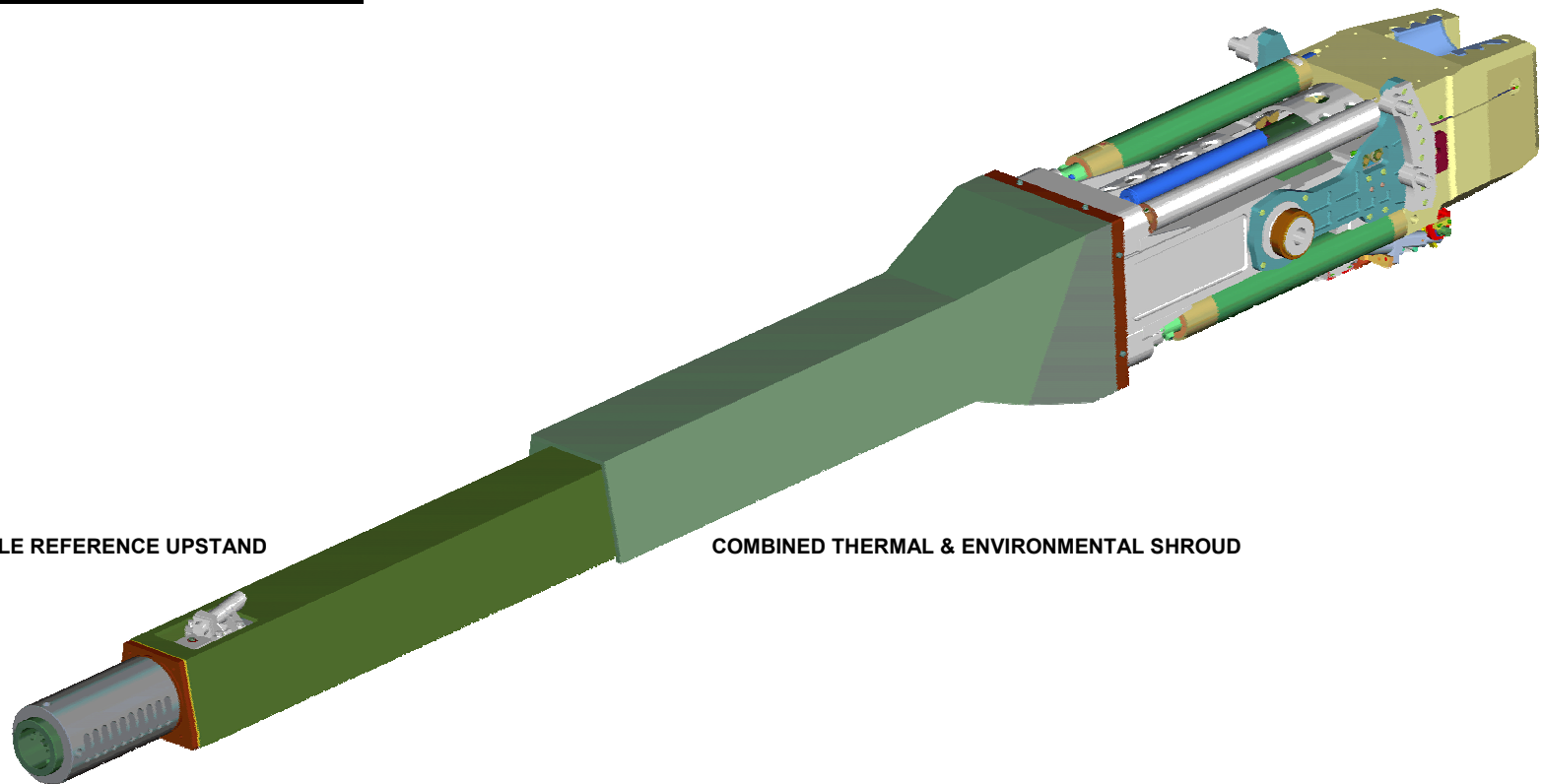


# LOS/BLOS ATD GUN DESIGN CONCEPT



ISO 9001 Certified  
FS15149

## GUN ASSEMBLY



MUZZLE REFERENCE UPSTAND

COMBINED THERMAL & ENVIRONMENTAL SHROUD

ATD 1 BLAST DEFLECTOR SHOWN THIS VIEW



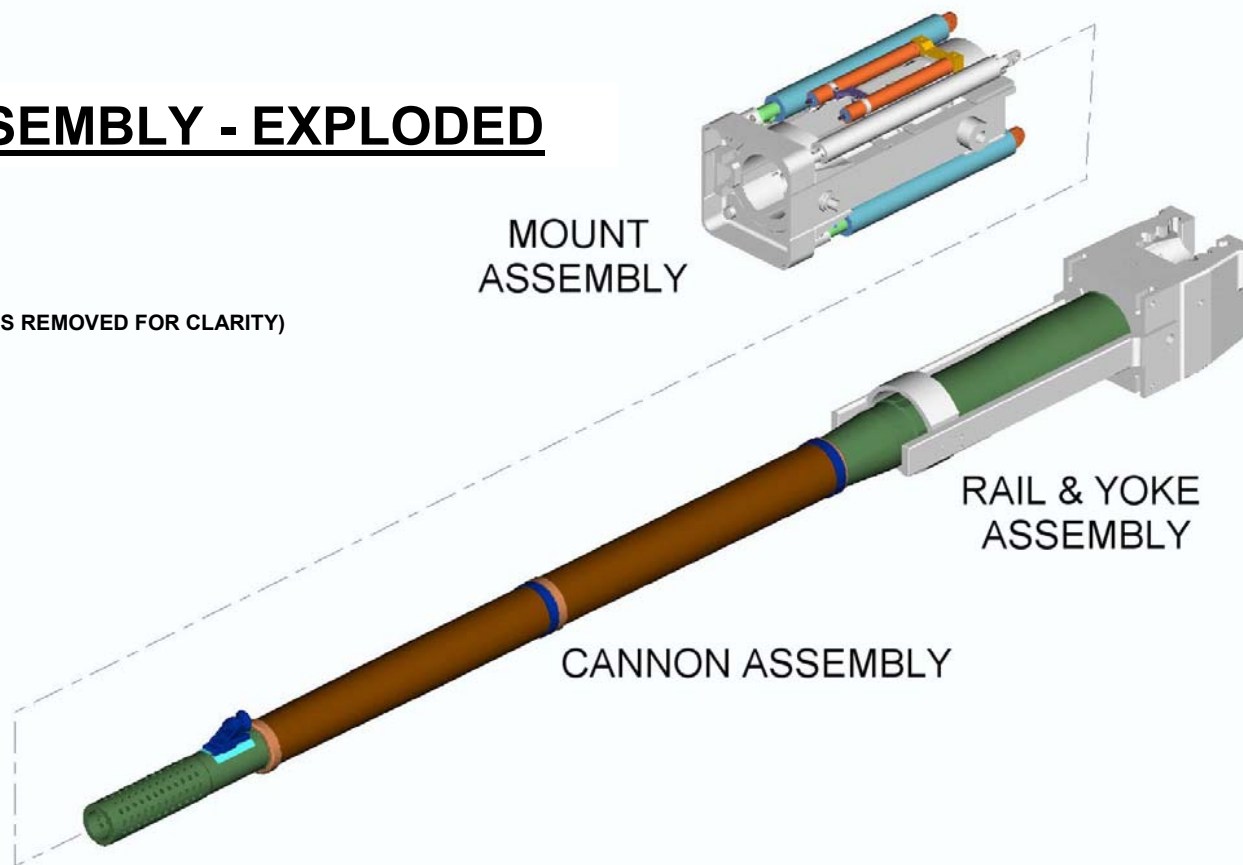
# LOS/BLOS ATD GUN DESIGN CONCEPT



ISO 9001 Certified  
FS15149

## GUN ASSEMBLY - EXPLODED

(SHROUDS REMOVED FOR CLARITY)



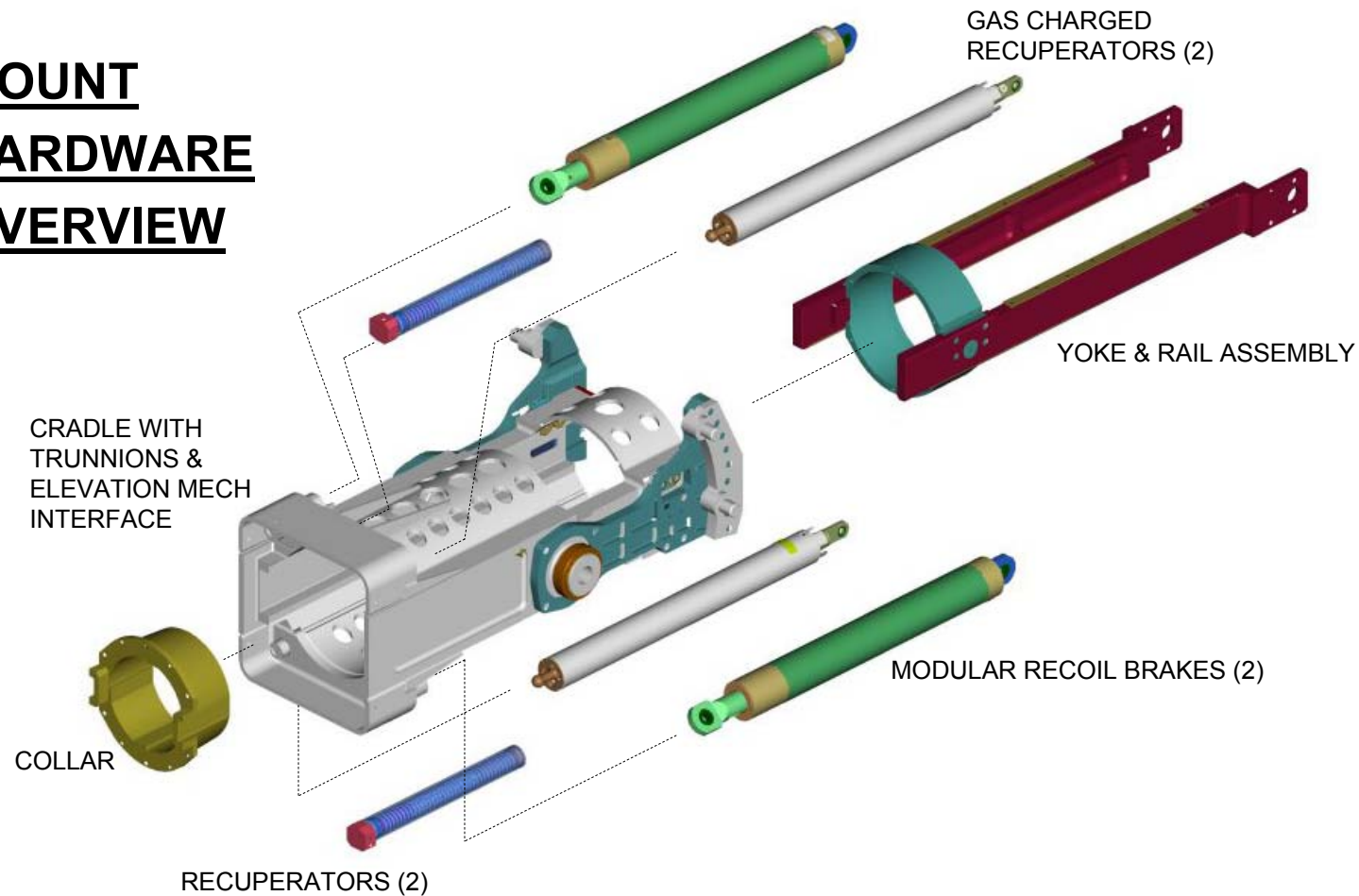


# LOS/BLOS ATD GUN DESIGN CONCEPT



ISO 9001 Certified  
FS15149

## MOUNT HARDWARE OVERVIEW



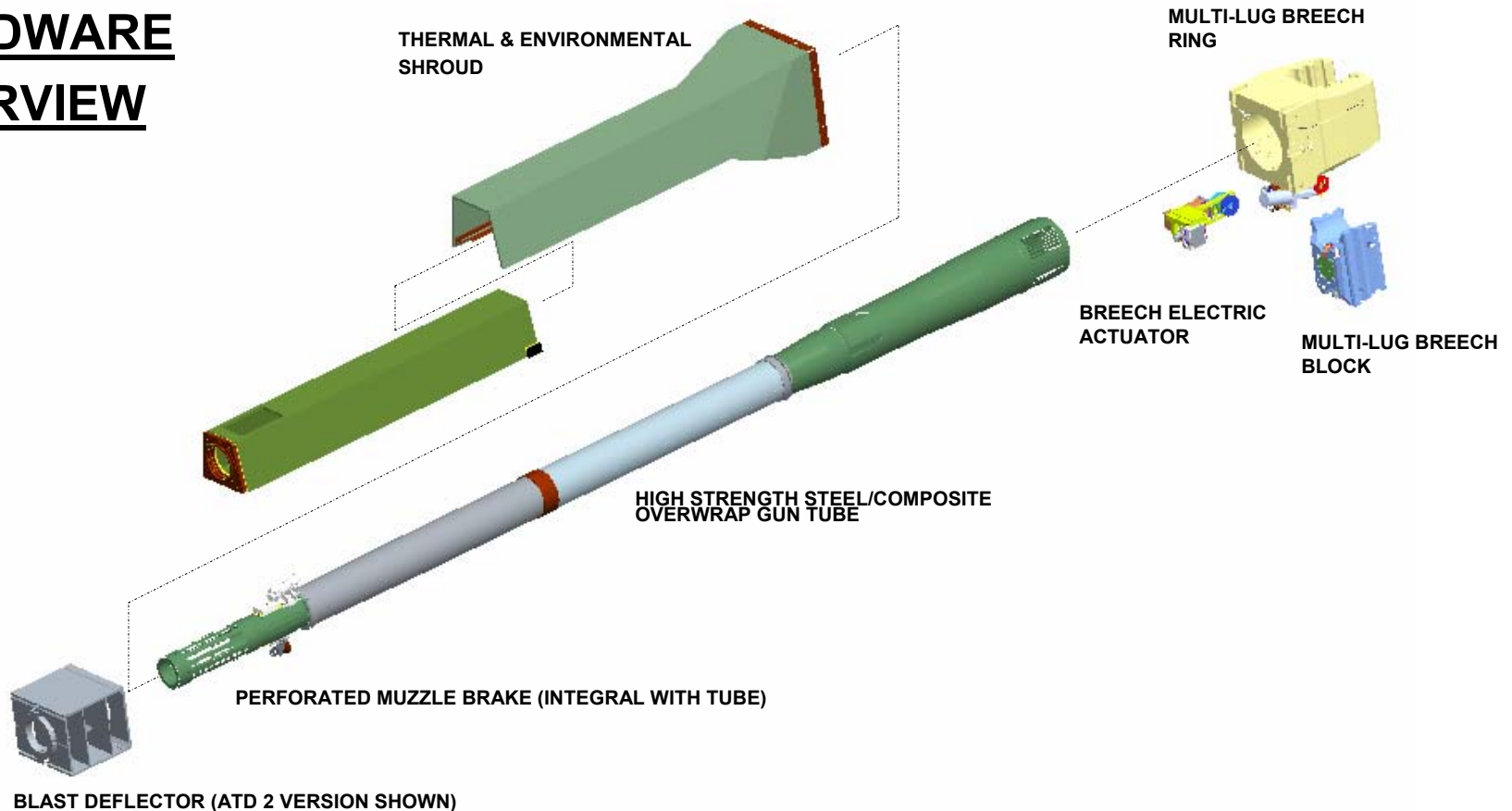


# LOS/BLOS ATD GUN DESIGN CONCEPT



ISO 9001 Certified  
FS15149

## CANNON HARDWARE OVERVIEW





# LOS/BLOS ATD GUN DESIGN CONCEPT (ATD # III.WP.2003.01)



ISO 9001 Certified  
FS15149

Capability	Current Capability (Baseline )	LOS/BLOS ATD	
		Minimum	Goal
<ul style="list-style-type: none"> <li>• Armament               <ul style="list-style-type: none"> <li>• Gun weight (lbs)</li> <li>• Gun elevation</li> <li>• Recoil &amp; Ammo Volume</li> <li>• Stowed Rounds</li> <li>• Weapon Recoil Force</li> <li>• Weapon position error (LOS)</li> </ul> </li> <li>• Ammunition               <ul style="list-style-type: none"> <li>• Advanced KE Armor Penetration</li> <li>• MRM – PSSK</li> <li>• Warheads:                   <ul style="list-style-type: none"> <li>Warhead – SC L/D (pen) Capability</li> </ul> </li> </ul> </li> <li>Precision Ignition Demo</li> </ul>	<p>6700 lbs</p> <p>20°</p> <p>4.5 m<sup>3</sup> (Abrams)</p> <p>42 (Abrams)</p> <p>160,000 Lbf</p> <p>.75 mil (EI and Az) (M1) dynamic</p> <p>M829A2 @ 2km</p> <p>N/A</p> <p>1.7 Armor</p> <p>T2 s of 3 ms (abrams)</p>	<p>4,400 Lbs</p> <p>30°</p> <p>3.5 m<sup>3</sup></p> <p>38</p> <p>90,000 Lbf</p> <p>.5 mil (EI and Az) dynamic</p> <p>Advanced Armor Threat @2km</p> <p>Pssk (class) 2-12km</p> <p>1.0 (class) Armor</p> <p>T2 s of 0.5 ms</p>	<p>4000 Lbs</p> <p>50°</p> <p>3.5 m<sup>3</sup></p> <p>43</p> <p>85,000 Lbf</p> <p>.35 mil (EI and Az) dynamic</p> <p>Advanced Armor Threat @4km</p> <p>Pssk (class) 2-16km</p> <p>1.0 (class + 30%) Armor, personnel, Bunker, Urban Helicopter</p> <p>T2 s of 0.1 ms</p>

# LOS/BLOS ATD GUN TEST RESULTS/STATUS

- **ATD GUN FIRING TEST PHASE – COMPLETED TO DATE AT APG**
  - **97 ROUNDS FIRED**

40 - M829A3

5 - M829A2

25 - M865

40 - M831A1

10 - M829A2 (PRECISION IGNITION MOD)

3 - MRM-CE SLUG

3 - MRM-KE SLUG

1 MRM-KE FINNED

- **TEST HARDWARE/PHASES COMPLETED**

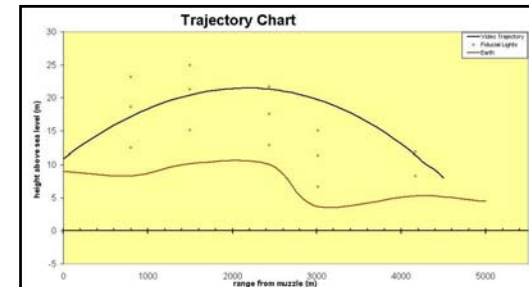
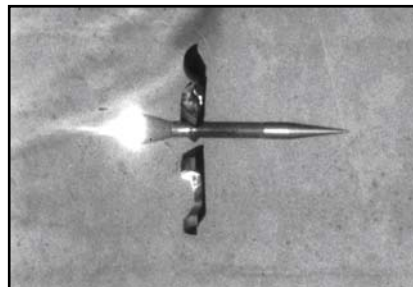
- **GUN TUBE STRUCTURAL INTEGRITY**
- **TRUNNION FORCE**
- **MUZZLE BRAKE EFFICIENCY**
- **MRM ROUNDS**
- **ACCURACY**
- **CMS TANTALUM LINER**



# LOS/BLOS ATD GUN TEST RESULTS/STATUS



- TEST SET UP AT ATC TRENCH WARFARE II FIRING RANGE
- MULTIPLE SOFT TARGET RANGE UP TO 5000M LOS, VIDEO SCORING
- 2 SEPARATE LOF ALLOW DU AND HEAT TO BE FIRED
- FIRE CONTROL DATA COLLECTION
- HIGH SPEED PHOTOGRAPHY, MUZZLE EXIT BALLISTICS
- NEAR REAL-TIME PROCESSING USING TEST SITE INTEGRATION
- RANGE ALLOWED MRM FIRING TO 12 KM





# LOS/BLOS ATD GUN TEST RESULTS/STATUS



ISO 9001 Certified  
FS15149

- **ATD GUN FIRING TEST RESULTS TO DATE –**
  - **COMPOSITE JACKETED GUN TUBE FIRED & STRAIN MEASURED**
  - **STRUCTURAL INTEGRITY DEMONSTRATED, PERFORMING WELL.**
  - **TRUNNION FORCE MEASUREMENTS:**
    - **PRELIMINARY RESULTS INDICATE GOOD AGREEMENT WITH PREDICTIONS**
    - **PEAK FORCES FIRING M829A3 WITH MUZZLE BRAKE < 65,000 LBS**
    - **MUZZLE BRAKE EFFICIENCY GOAL OF > 25% FIRING THE M829A3 ROUND DEMONSTRATED.**
  - **MRM-KE ROUND FIRED TO MAX RANGE (30° ELEVATION)**
    - **12 KM RANGE DEMONSTRATED, ACTUAL RANGE 12.8 KM.**
    - **PROPER FIN DEPLOYMENT THROUGH MUZZLE BRAKE DEMONSTRATED.**



# LOS/BLOS ATD GUN TEST RESULTS/STATUS



ISO 9001 Certified  
FS15149

- **RESULTS (cont'd)**
  - **INITIAL EROSION TESTING ON CYLINDRICAL MAGNETON SPUTTER (CMS) COATED (TANTULUM) LINER (~2')**
  - **ACCURACY TESTING - TARGET IMPACT DISPERSION (TID)**
    - **M829A3 INITIAL TID COMPLETED**
    - **M865 & M831A1'S GOOD RESULTS – TID WITHIN REQUIREMENTS.**
  - **BREECH BLOCK WITH AMMO DATA LINK (ADL).**
    - **FUNCTIONALITY, STRUCTURAL INTEGRITY OF DUAL DATA PIN ADL DEMONSTRATED.**
    - **SINGLE PIN ADL (GERMAN) SYSTEM DEMONSTRATED.**
    - **PRECISION IGNITION DEMONSTRATION.**
    - **BREECH ACTUATOR HARDWARE DEMONSTRATED**
  - **ULTRA HIGH STRENGTH STEEL TUBE FIRED**



# LOS/BLOS ATD GUN TEST RESULTS/STATUS



**LIGHTWEIGHT 120 MM GUN ASSEMBLY AT  
ABERDEEN TEST CENTER – 19 OCT 04.  
NOTE MICROPHONES TO RECORD BLAST  
OVERPRESSURE, ADDITIONAL RISERS  
UNDER GUN 'KNEES' TO OBTAIN MORE  
ACCURATE GROUND REFLECTION DATA.**

**PENCIL PROBE AND HULL MOUNT  
SIMULATOR MICROPHONES WERE  
CUSTOM DESIGNED AND FABRICATED  
BY ATC BALLISTICS AT THE REQUEST OF  
THE BENET LABORATORIES**

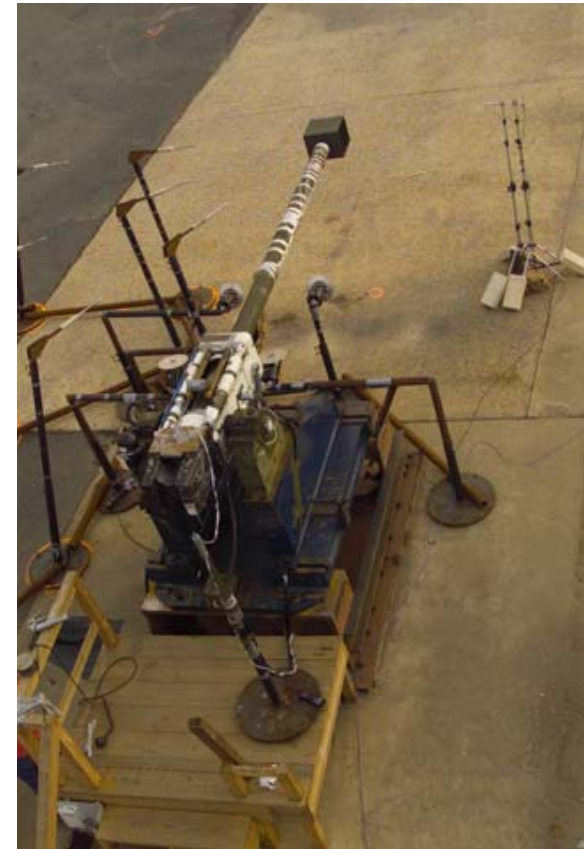




# LOS/BLOS ATD GUN TEST RESULTS/STATUS



ISO 9001 Certified  
FS15149



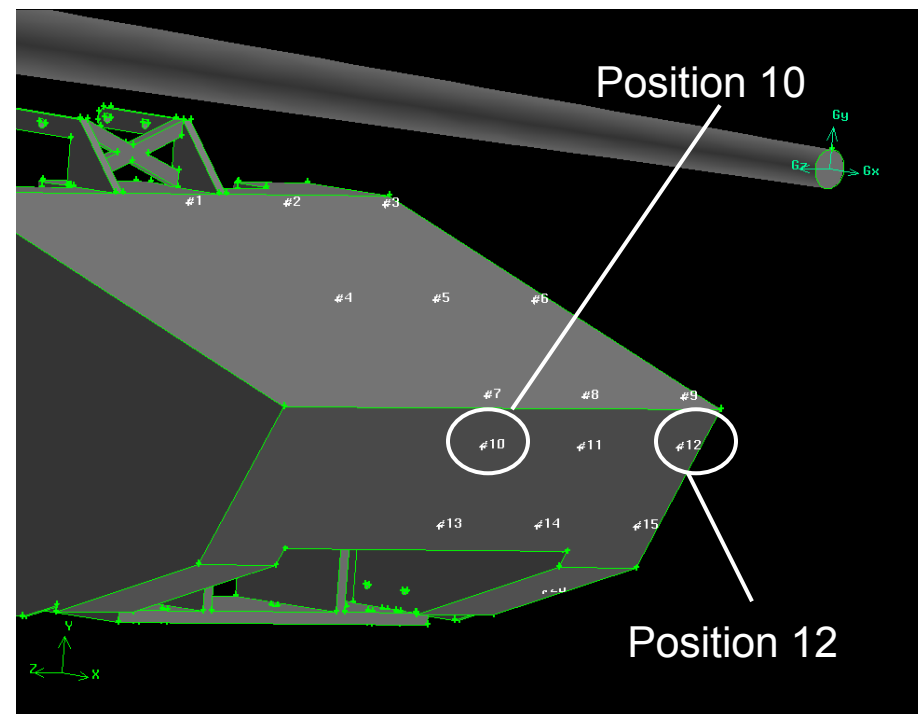
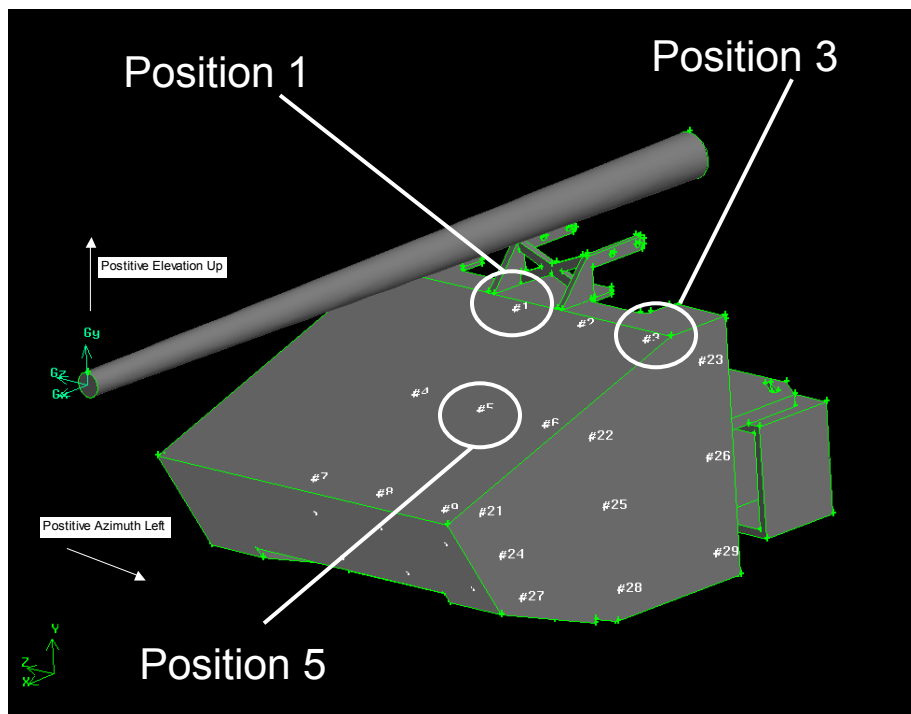


# LOS/BLOS ATD GUN TEST DATA



ISO 9001 Certified  
FS15149

## HULL POSITIONS MEASURED WITH CHASSIS SIMULATOR GAGES

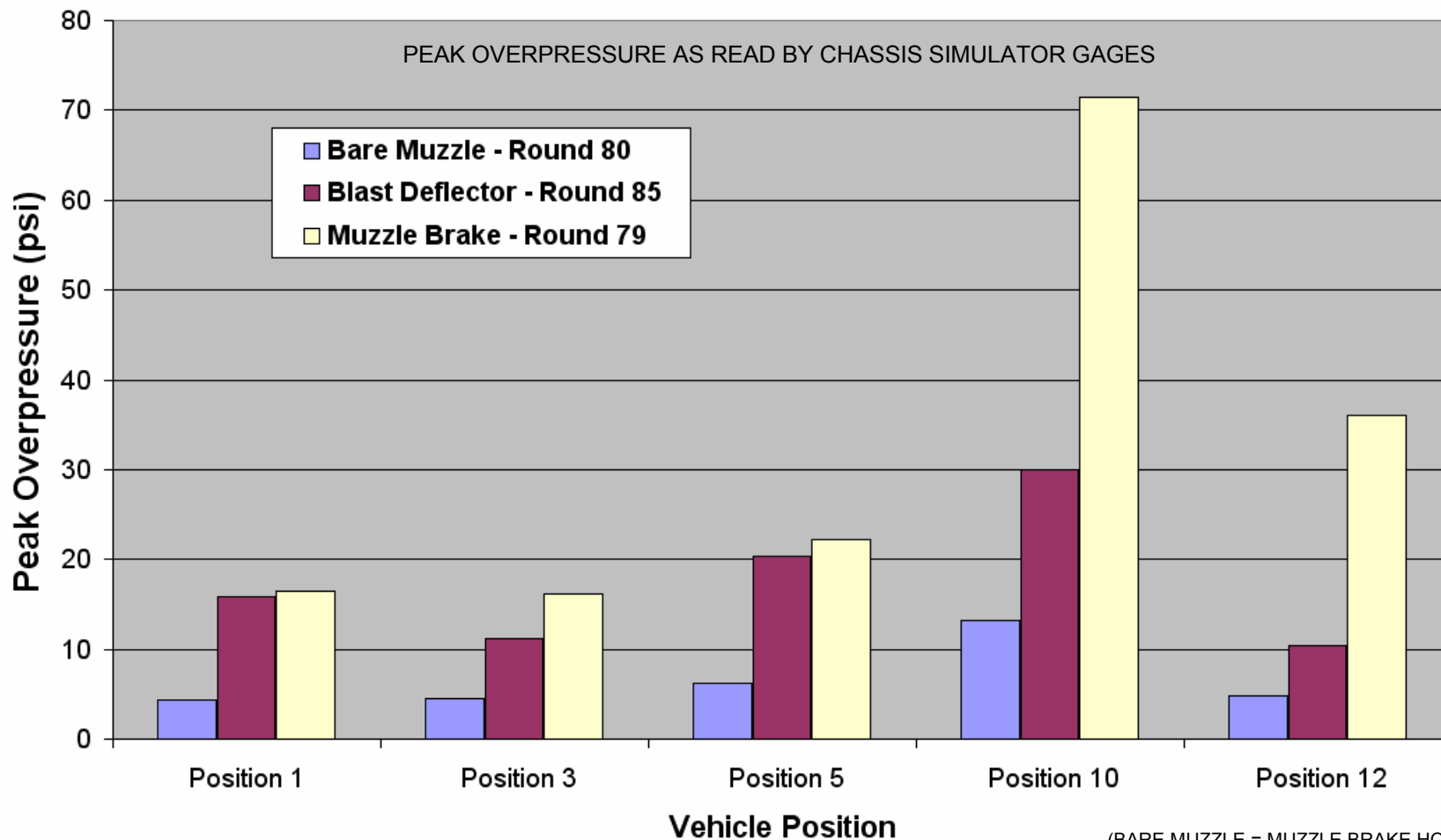




# LOS/BLOS ATD GUN TEST DATA



ISO 9001 Certified  
#S15149



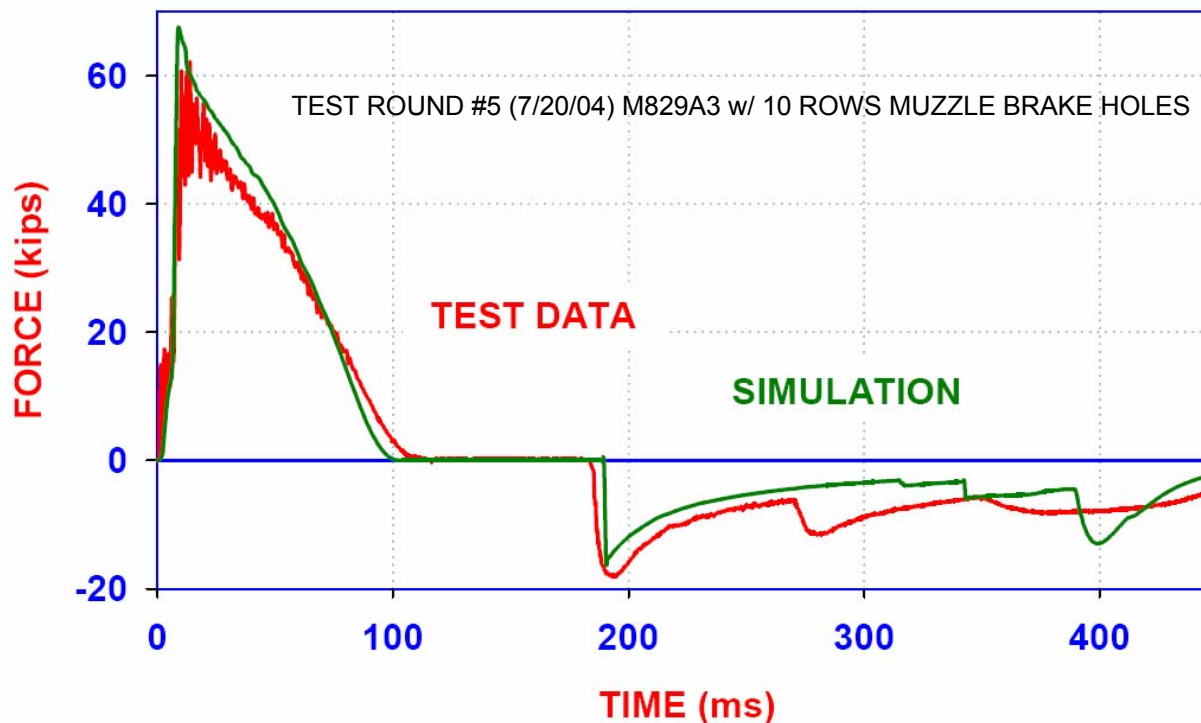


# LOS/BLOS ATD GUN TEST DATA



ISO 9001 Certified  
FS15149

## TOTAL BRAKE FORCE vs TIME



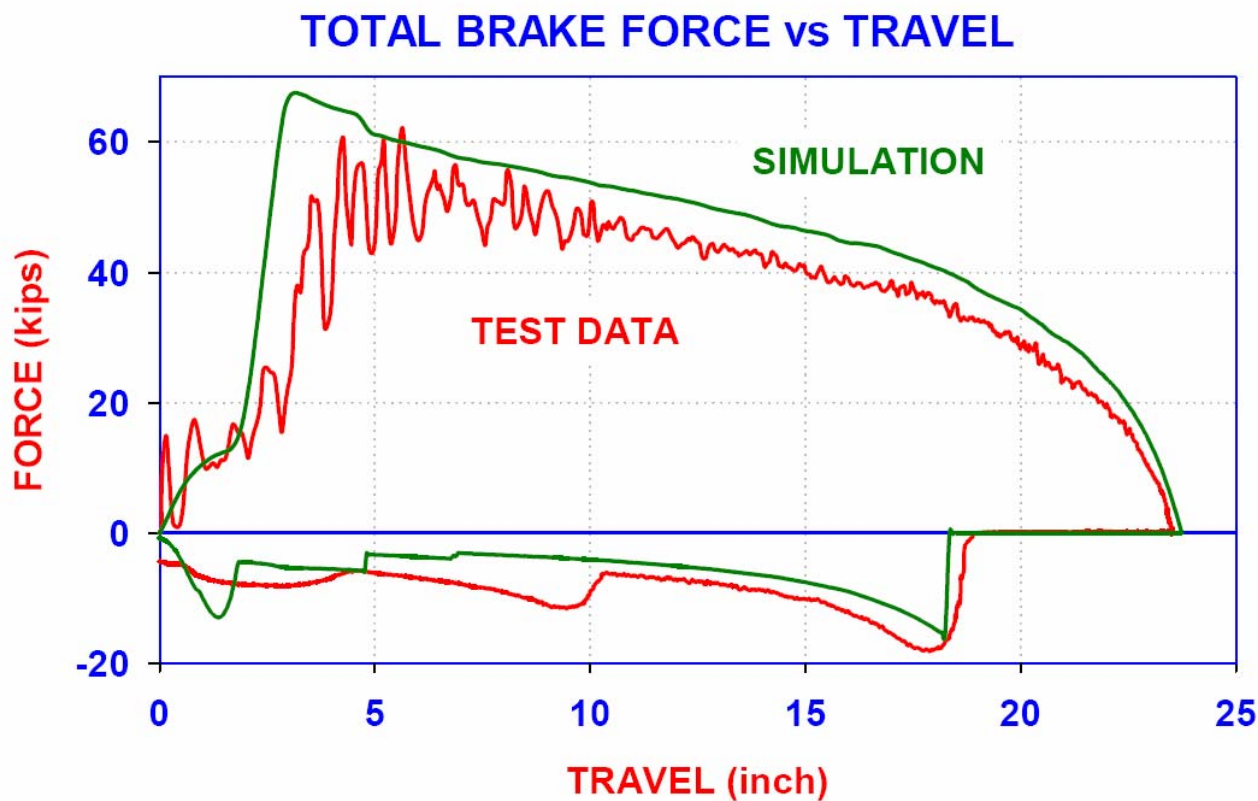
ROUND	CARTRIDGE	IMPULSE (LBSEC)	CONFIGURATION
5	M829A3	5,232	Full Muzzle Brake
6	M829A3	5,315	Full Muzzle Brake
7	M829A3	5,360	Full Muzzle Brake



# LOS/BLOS ATD GUN TEST DATA



ISO 9001 Certified  
FS15149



ATD #1 RECOIL SYSTEM TEST RESPONSE TEST ROUND #3 (7/20/04) M829A2 w/ 10 ROWS MUZZLE BRAKE HOLES



# LOS/BLOS ATD GUN PRELIMINARY TEST RESULTS



ISO 9001 Certified  
FS15149

## ROUND M829A2 @ 70DegF

ATD - TEST	BALLISTIC IMPULSE	IMPULSE at TRUNNION	PERCENT REDUCTION
1 (3)	6428	4818	25.0
2 (10)	6327	4803	24.1

## ROUND M831A1

ATD - TEST	BALLISTIC IMPULSE	IMPULSE at TRUNNION	PERCENT REDUCTION
1 (3)	5645	4322	23.4
2 (10)	5560	4442	20.1

## ROUND M865

ATD - TEST	BALLISTIC IMPULSE	IMPULSE at TRUNNION	PERCENT REDUCTION
1 (3)	4833	3628	24.9
2 (10)	4825	3549	26.4



# LOS/BLOS ATD GUN TEST RESULTS/STATUS



ISO 9001 Certified  
FS15149





# LOS/BLOS ATD GUN TEST RESULTS/STATUS



ISO 9001 Certified  
FS15149

**ATD MOCK GLACIS ASSEMBLED AT ABERDEEN TEST CENTER**





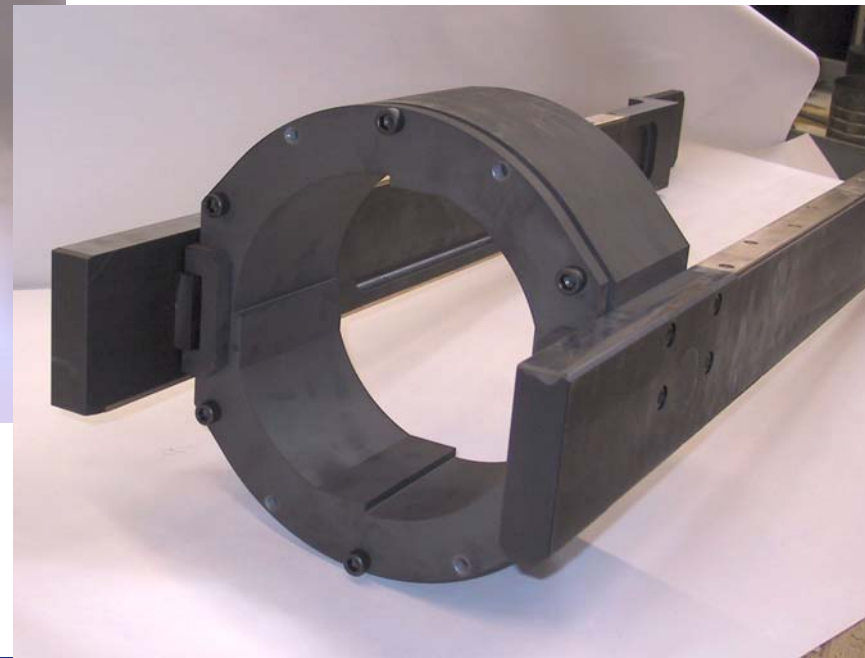
# LOS/BLOS ATD GUN TEST RESULTS



ISO 9001 Certified  
FS15149



**ATD 3 TITANIUM  
RAILS, YOKE & ADAPTOR**





# LOS/BLOS ATD GUN TEST RESULTS/STATUS



ISO 9001 Certified  
FS15149



**ENVIRONMENTAL/SIGNATURE  
SHROUD COMPOSITE SECTIONS  
(POST CURE) MADE AT BENET**

**ENVIRONMENTAL/SIGNATURE  
SHROUD ASSEMBLIES BEING  
TEST FIT TO TUBE AT BENET**





# LOS/BLOS ATD GUN IN HOUSE TESTING



ISO 9001 Certified  
5545410

## COMPOSITE TUBE (ATD 3) STRAIN TESTING AT BENET

### HIGH TENSION COMPOSITE SPECIMEN

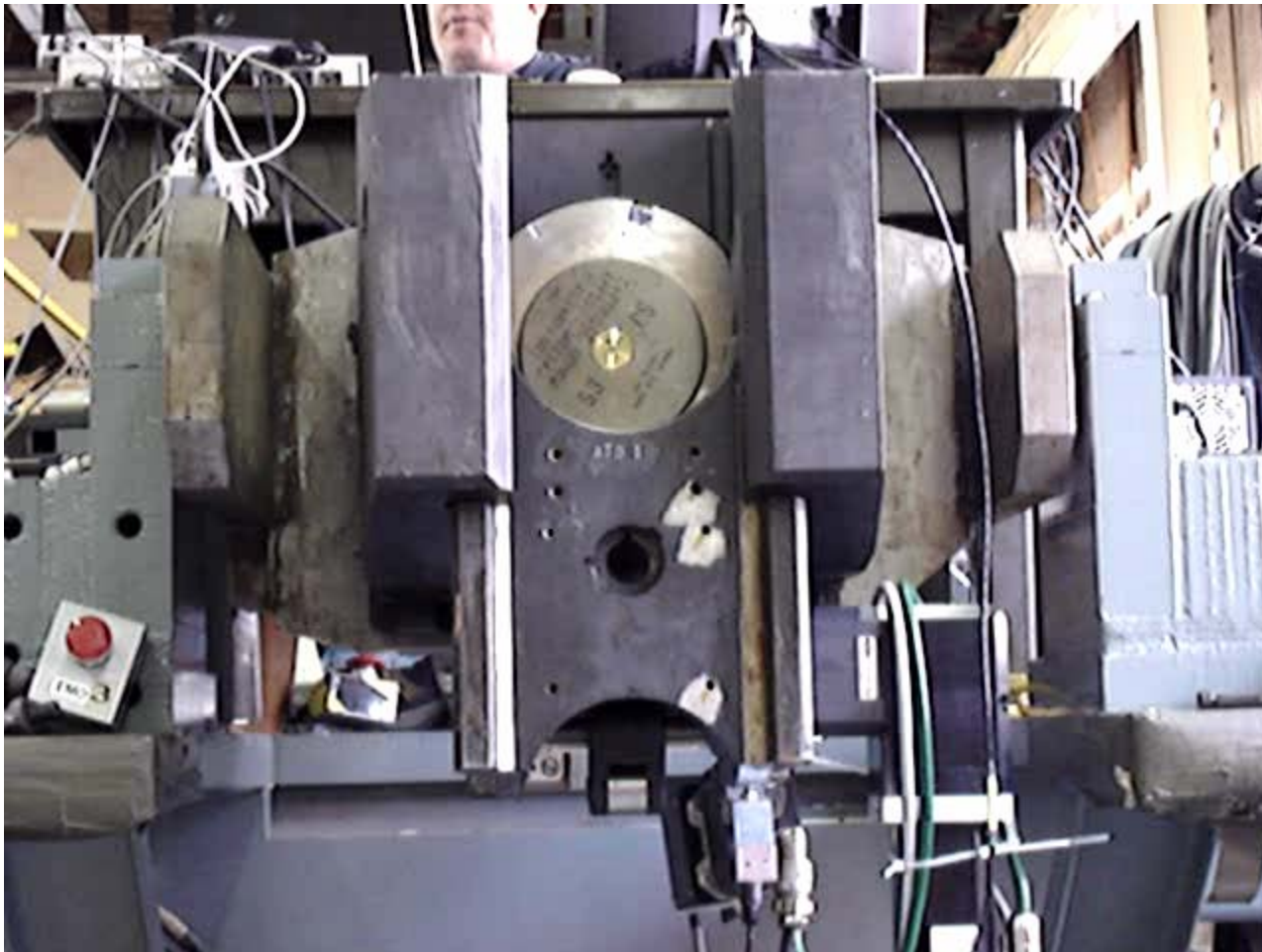




# LOS/BLOS ATD GUN IN HOUSE TESTING



ISO 9001 Certified  
FS15149





# LOS/BLOS ATD GUN PATH FORWARD



ISO 9001 Certified  
FS15149

- **COMPLETE ANALYSIS OF ALL TEST DATA OF LOS/BLOS ATD TEST PHASES (ONGOING THROUGH MAY 05) AND INCORPORATE INTO GUN TECHNICAL DATA PACKAGE**
- **START NEW STO PROGRAM “LIGHTWEIGHT ARMAMENT ENHANCEMENTS”**
  - **EXPLORE/MATURE HIGHER RISK ARMAMENT WEIGHT REDUCTIONS AND ACCURACY ENHANCEMENTS**
  - **DEMONSTRATE TECHNOLOGIES FOR TRANSITION INTO SDD**
- **SDD PROGRAM START**
  - **TAILOR GUN INTERFACES FOR THE MCS**
  - **REFINE TECHNICAL DATA PACKAGE TO OPTIMIZE COST & PERFORMANCE**
  - **INCORPORATE INTERFACES FOR NEW MUNITIONS**



# FCS/MCS LW120 GUN DESIGN CONCEPT – GUN ASSY WEIGHT



ISO 9001 Certified  
FS15149

	M256 (M1A2)	SDD Estimate	LAEP Estimate
Breech Ring & Block Assemblies	1525	1,072	842
Breech Mech. Housing Assembly	(included)	42	42
Breech Actuator Assembly	N/A	43	43
Gun Tube	2350	1960	1590
Thermal Shrouds	180	77	77
MRS	0	0	0
Blast Deflector	N/A	90	65
Cradle Assembly	2560	532	532
Replenisher Assembly	(included)	18	18
Elevation interface plates	(included)	78	78
Recoil Brakes (2)	(included)	164	100
Recuperators (2)	(included)	84	75
Rails, Yoke, Adapter	(included)	283	168
Bore Evacuator	50	N/A	N/A
<b>Total Weight (lbs)</b>	<b>6,665.00</b>	<b>4,443.00</b>	<b>3,630.00</b>

-180 LBS - FULL  
THREAD  
-50 LBS - TI BLOCK

-200 LBS - COMPOSITE  
-100 LBS - SUHSS  
-70 LBS - DUAL  
AUTOFRETTAGE

-25 LBS - BLAST  
DEFLECTOR

-64 LBS - BRAKES  
-9 LBS - RECUPS

-115 LBS - ATD DESIGN  
DEMO IN LAEP

813 LBS  
savings

M256 GUN WEIGHT DOES NOT INCLUDE ROTOR SHIELD

LAEP WEIGHT SAVINGS OF 813 LBS

SDD ESTIMATE INCLUDES OTHER WEIGHT REDUCTION INITIATIVES NOT SHOWN IN PREVIOUS SLIDES



# LOS/BLOS ATD GUN ACCOMPLISHMENTS



ISO 9001 Certified  
FS15149

ATD GUN MOD 1 FIRING DEVELOPMENTAL MRM CARTRIDGE 19 JUL 04 – SHOT 28





# LOS/BLOS ATD GUN ACCOMPLISHMENTS - SUMMARY



ISO 9001 Certified  
FS15149

- **ACCOMPLISHMENTS**
  - **ACHIEVED A SYSTEM WEIGHT OF 4,240 POUNDS (ALL STEEL TUBE)**
  - **IMPULSE WITHIN SPECIFIED LIMIT**
  - **INITIATED TESTING DECEMBER 2003**
  - **DEMONSTRATED A MUZZLE BRAKE EFFICIENCY OF 25%**
  - **TEST FIRED TWO ITERATIONS OF BLAST DEFLECTOR TO REDUCE BLAST OVERPRESSURE**
  - **TEST FIRED TWO ITERATIONS OF A COMPOSITE OVERWRAPPED GUN TUBE (JUL 04)**
  - **SUCCESSFULLY PROOF TESTED AN ULTRA HIGH STRENGTH GUN STEEL TUBE (OCT 04)**
  - **ACHIEVED TRL 6 IN OCTOBER 2004 (CANNON) WITH ALL STEEL TUBE**





# 40<sup>Th</sup> Annual Armament Systems- Guns-Ammunition Rockets Missiles

## Missile Systems Lethality Enhancement through the use of a Conducting Aerosol Plasma Warhead 27 April 2005

Allen Stults

US Army RDECOM AMRDEC

AMSRD-AMR-PS-WF

[allen.stults@us.army.mil](mailto:allen.stults@us.army.mil)



# Multi-Functional Warheads Are Lethal Against a Large Target Set

- Enhanced blast and fragmenting warheads have been successfully combined with shaped charges to service multiple target types with the same missile warhead, such as in Joint Common Missile. These are termed multi-purpose warheads.
- The next class of future missile systems can be further improved by adding RF effects to broaden the target set and enhance lethality
- The first step is to demonstrate additional effects without degrading existing capabilities





# Multi-Effects Electromagnetic Warhead

**Develop and Integrate Warheads into Missile Systems to Destroy and Disable Electronic Systems and their Operators in Support of Combat Forces**

**Enhanced Blast for Personnel Lethality**



**Fragments for Equipment Lethality**

**EMP for Electronics**

Cell phone

Computer

Radio

Vehicle Ignition System

GPS Jammer



# Three Major Products From Missile Laboratory to Missile Programs

- Improved Anti-Armor Precursor Charge
- Enhanced GMLRS Bomblet or Cargo Round payload
- Next Generation 2.75" Rocket Warhead





# Baseline Warhead Trade Studies

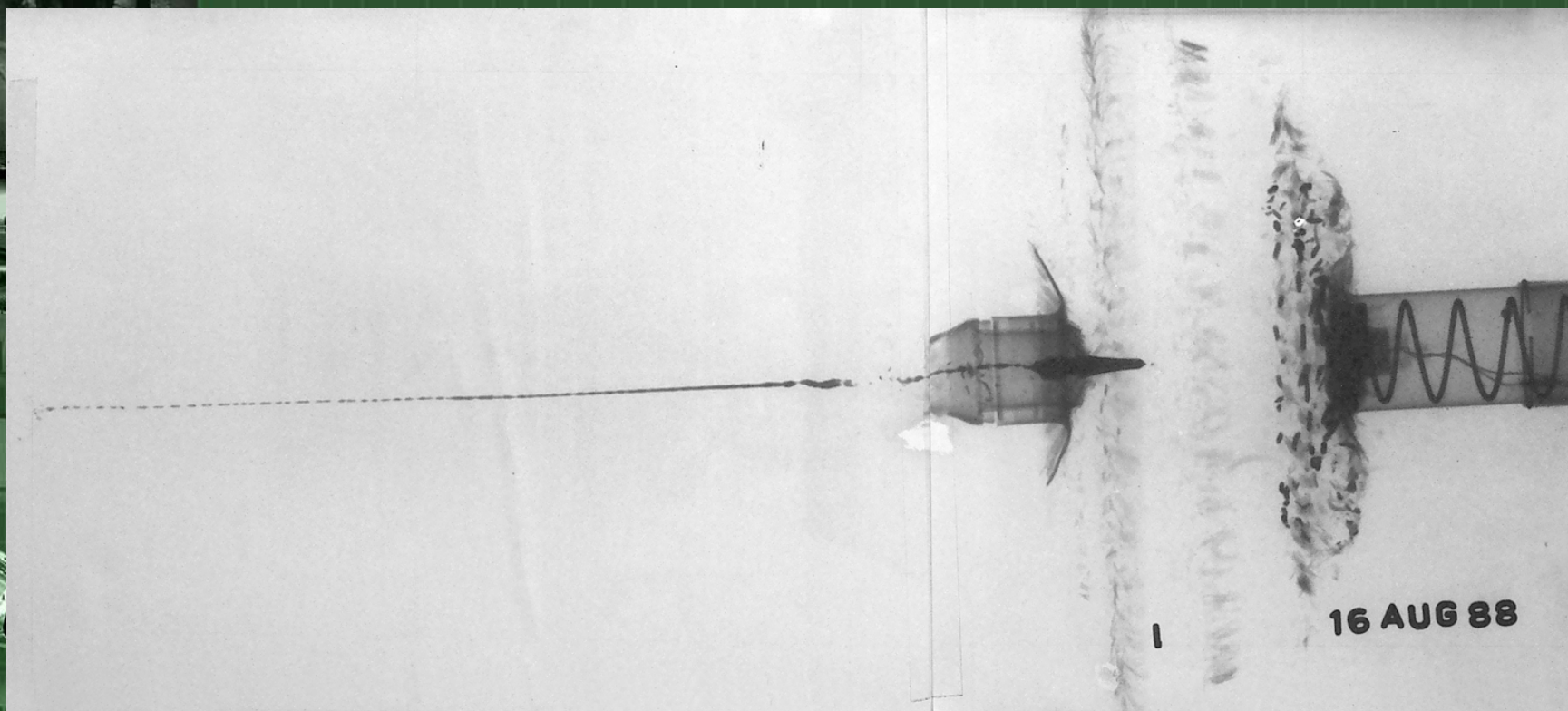
- EM Measurements of Detonations and Plasma Characterizations
- Non-Ideal Explosives for Shape Charges/  
Conductive Metal Antennas and Masonry destruction

Improved Seed Sources Program, SBIR leverage of FEG and FMG



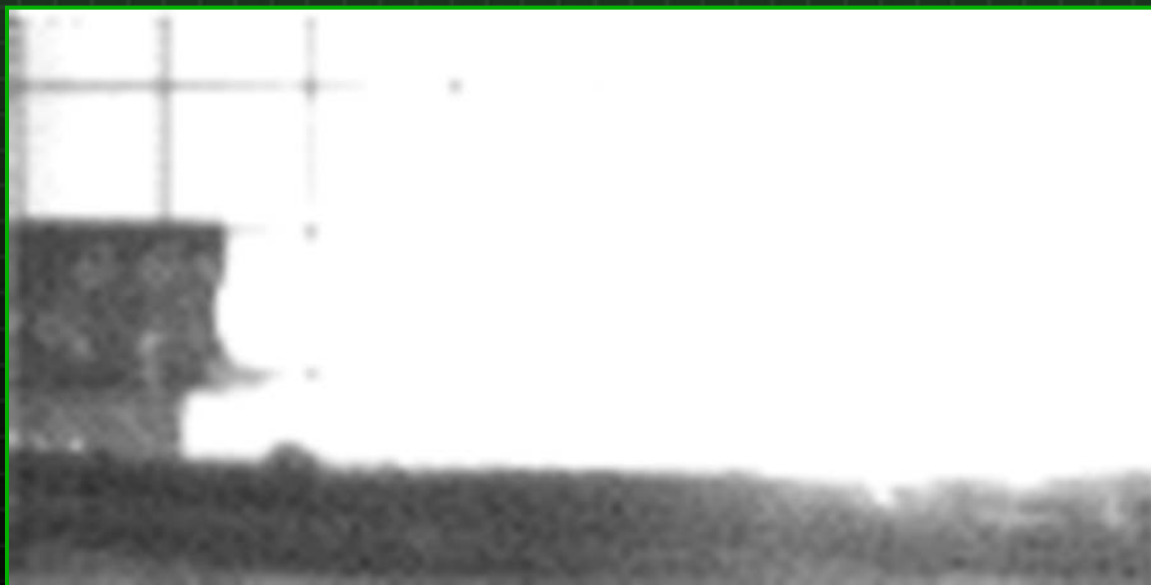


# TOW Tip Charge Flash X-ray





# Plasma Entrainment





# Test Set-Up





# Test Article N5 and Metal Fuel Rich Mix





# Filled test Article





# Representative Cover Plates



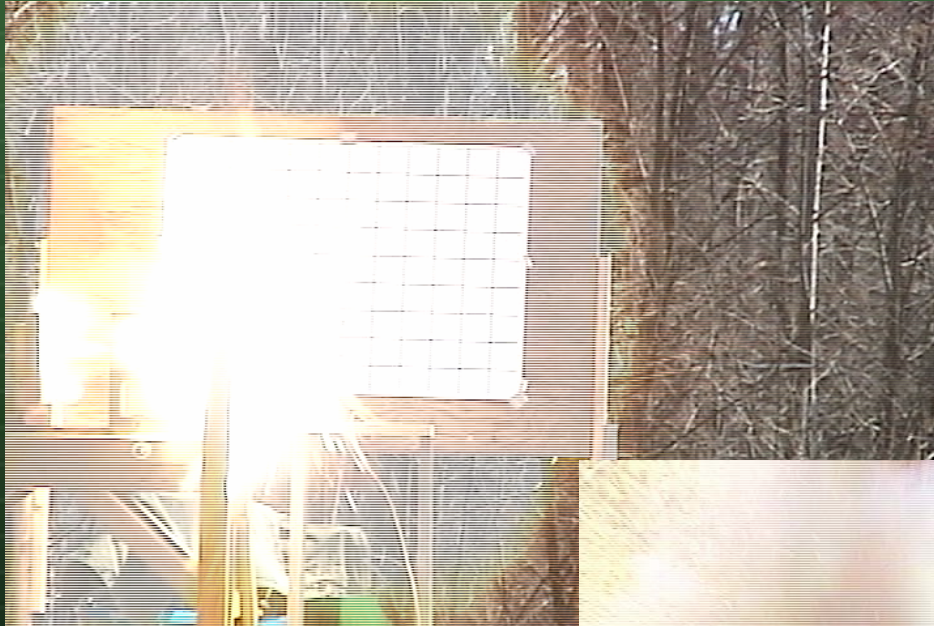


# Demonstration of Deflagration Effects on Masonry Targets

- Test various mixes of approximately 50 grams of aluminum powder pyrotechnic and thermite
- Gather fireball size, expansion rate and duration data for modeling efforts
- Investigating switch timing requirements to load dynamic plasma antenna
- Demonstrate robustness of masonry destructiveness at 10 CDs stand-off



# Test 1



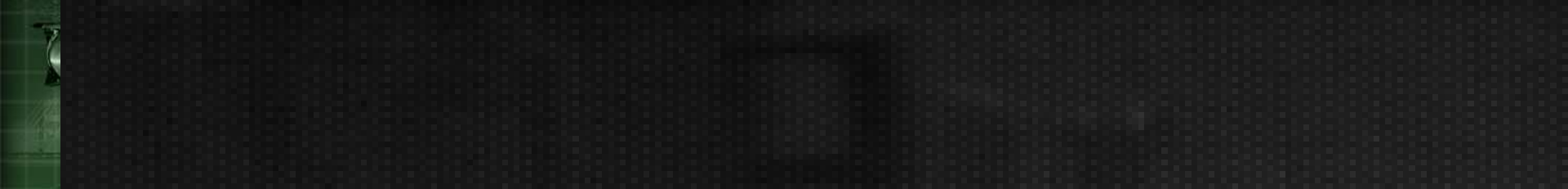


# Test 1 Video





# Test 1 – High Speed Video





# Test 1 – Masonry Destruction





## Test 2





## Test 3





# Test 4





# Test 5





## Test 6





# Test 7





## Conclusions and Plans

- Conductive Plasmas made from Deflagrating mixtures have significant destructive effects on masonry
- Significant Differences in Similar Mixes Allow the EM Designer a Robust set of Design Characteristics
- Temperature and Conductivity Effects will be further tested this Summer



Thanks

Joey Reed and Mike Kennemer for all  
their help in experimental conduct

George Arkoosh for his help in video  
production

Larry Altgilbers for his encouragement  
and advice



# Royal Navy Small Calibre Gun Research to Defeat the Small Boat Threat

27<sup>th</sup> April 2005

Jonathan Watkins

Surface Warfare Weapons Team

Naval Systems

Dstl Portsmouth West

UNCLASSIFIED

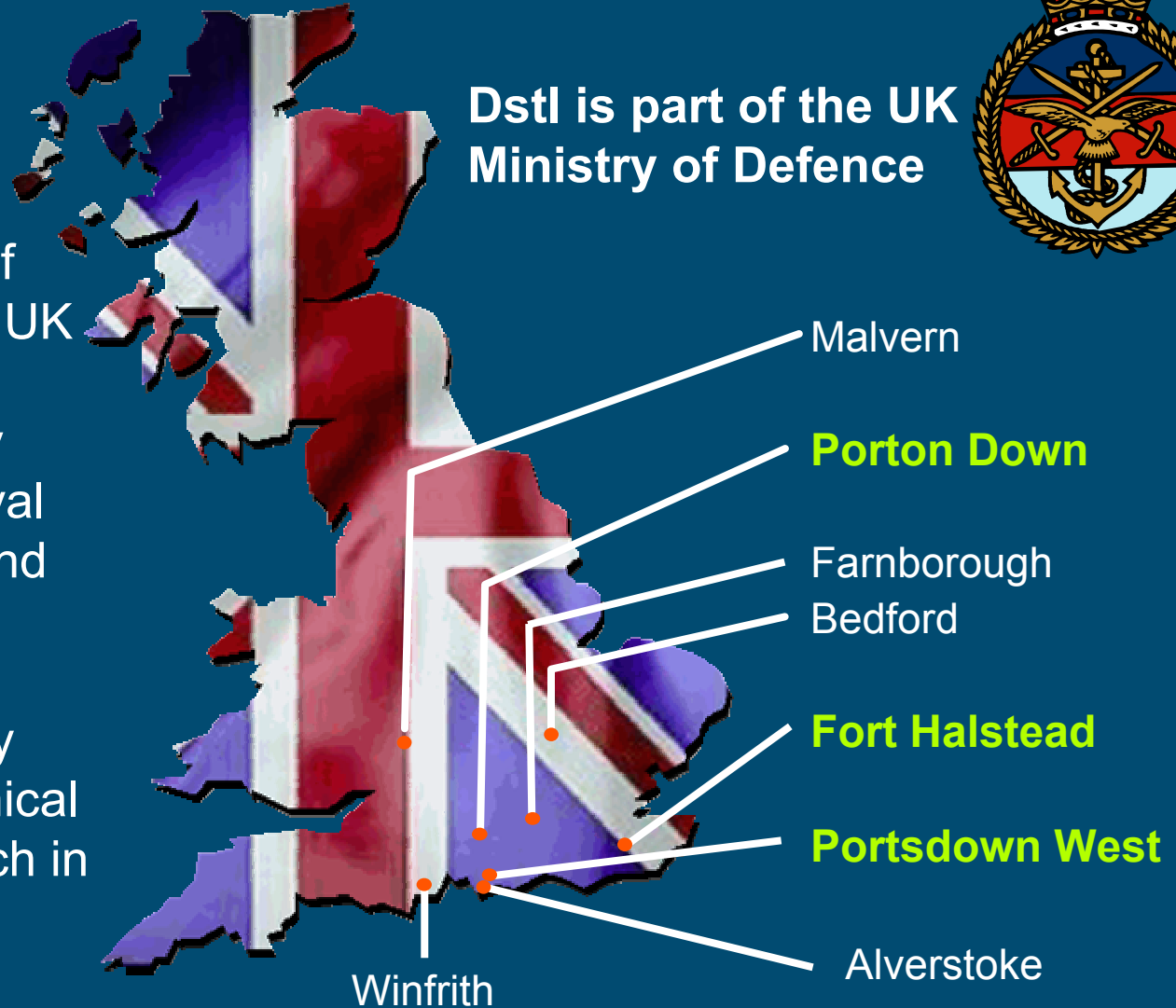


3000 Staff  
Based in a number of  
locations around the UK

Support to Capability  
Management for Royal  
Navy, British Army and  
Royal Air Force.

UK Government Only  
Research and Technical  
Oversight of Research in  
Industry.

Dstl is part of the UK  
Ministry of Defence



3 May, 2005  
© Crown Copyright Dstl 2005

UNCLASSIFIED



Dstl is part of the  
Ministry of Defence

# Dstl - Naval Systems Department

- The Naval Systems Department provides analysis and top-level platform and weapon systems advice in support of MOD decision making on Naval Systems.
- The Naval Systems Dept comprises of the following groups
  - Above Water Systems - (Surface Warfare - Weapon Systems Team)
  - Littoral Warfare (Operational Analysis)
  - ASW Capablility
  - Under Water Systems



# Fast In Shore Attack Craft (FIAC)



PLAY



# Existing Small Calibre Gun



e, used  
ements  
aft  
iary  
e (2km)  
ks by

# Operator Performance?



# HMS Somerset Trial

30mm Cannon - Remotely Controlled from Ops Room



# Alternative Cannon



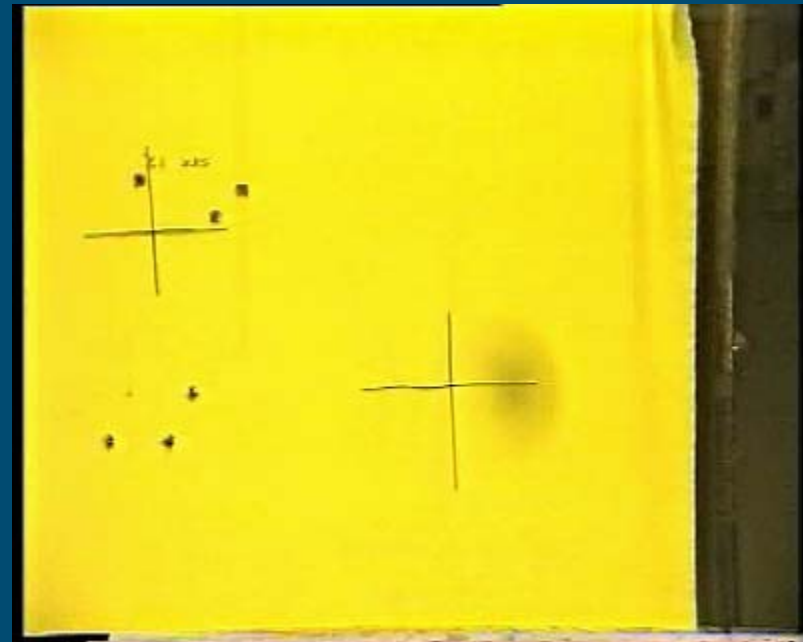
© MSI-DSL 2005 Published with Permission

30x173mm MK44 Bush Master II

**MSI**



© MSI-DSL 2005 Published with Permission



Proof Firings



3 May, 2005  
© Crown Copyright Dstl 2005

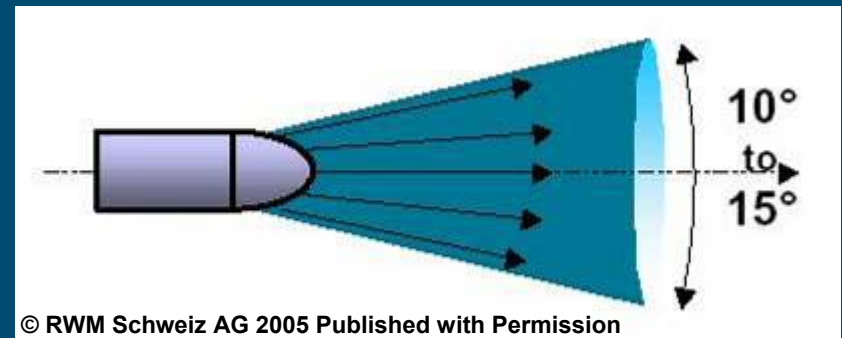
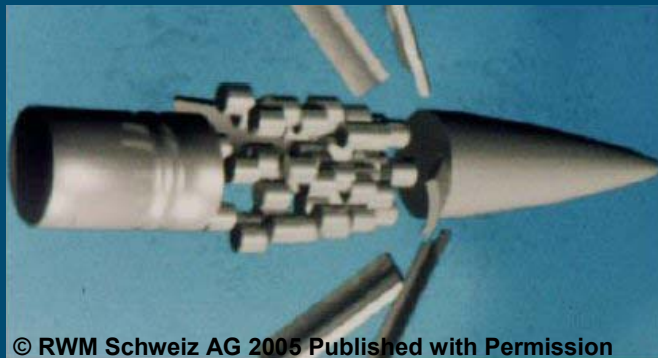
UNCLASSIFIED



Dstl is part of the  
Ministry of Defence

# Air Burst Munitions

- Key Points for 30x170mm RWM Schweiz AG
  - 162 Sub-Projectile Kinetic Energy Payload
  - Each 1.24 g
  - Programmed to Eject Payload (Burst) Ahead of target



- Potential Advantages of ABM
  - Increased chance of hitting target due to better coverage by sub-projectile payload
  - Hence provides Increased lethality against soft targets

# ABM Trial - Shoeburyness, Nov 2003

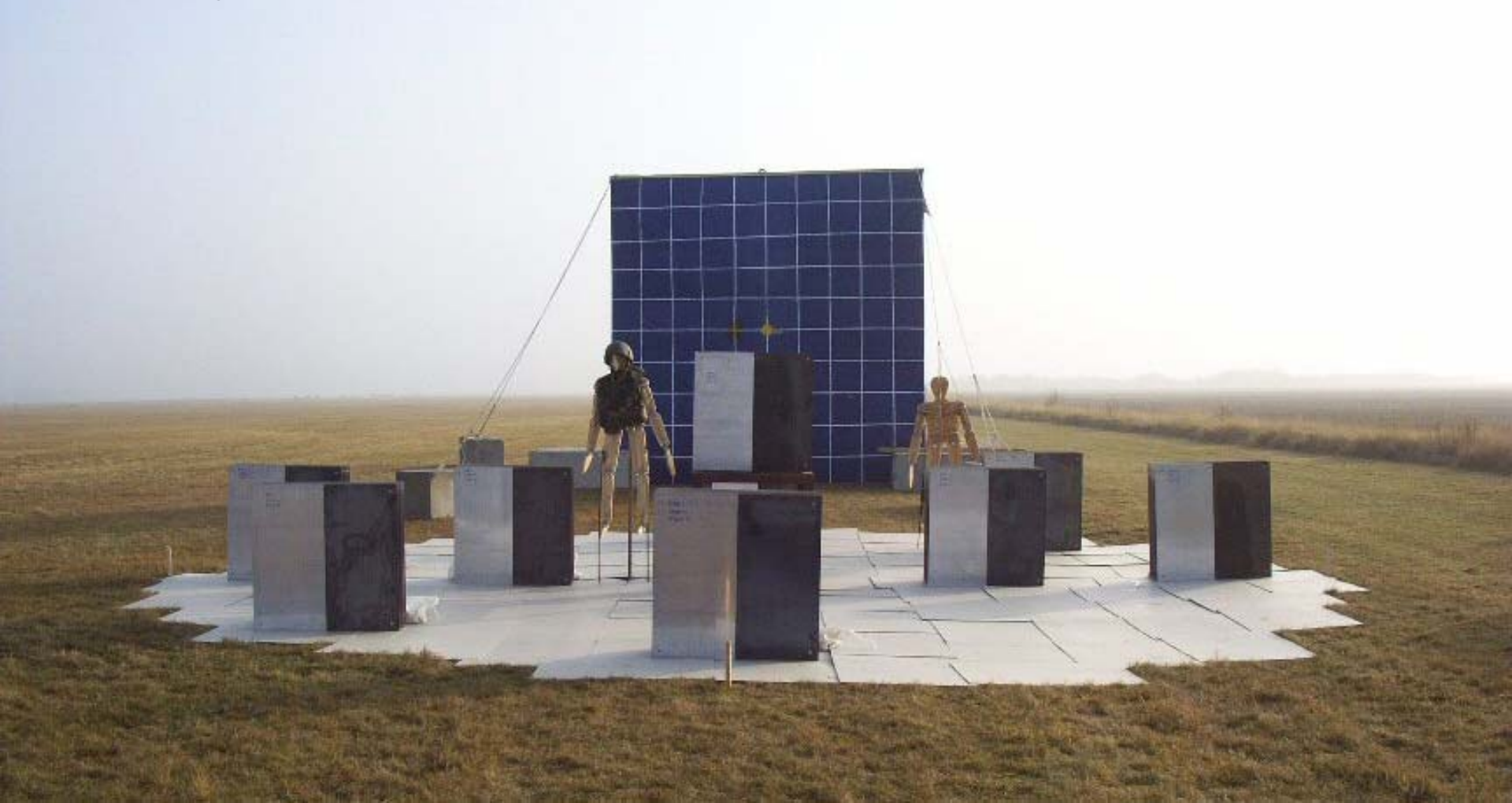
- Co-operation with USN and USMC & Industry



- Objectives of Trial
  - Assess ABM against representative target
  - Assess Penetration of fragments
  - Assess Fragment Dispersion
  - Assess Burst Point Placement

# The Target Matrix

1km Target Matrix 11th November 2003



# The Churchend Range

11th November 2003



3 May, 2005  
© Crown Copyright Dstl 2005

UNCLASSIFIED



Dstl is part of the  
Ministry of Defence

# ABM Burst Point Capture

1.5km Range



Front Camera



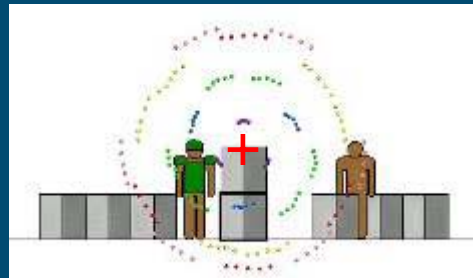
Side Camera

# Target Plate Analysis

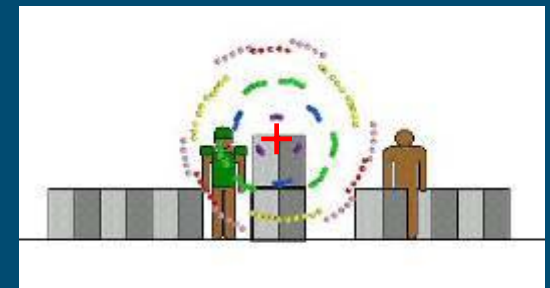
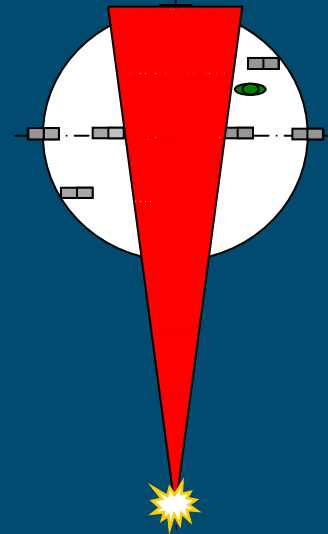
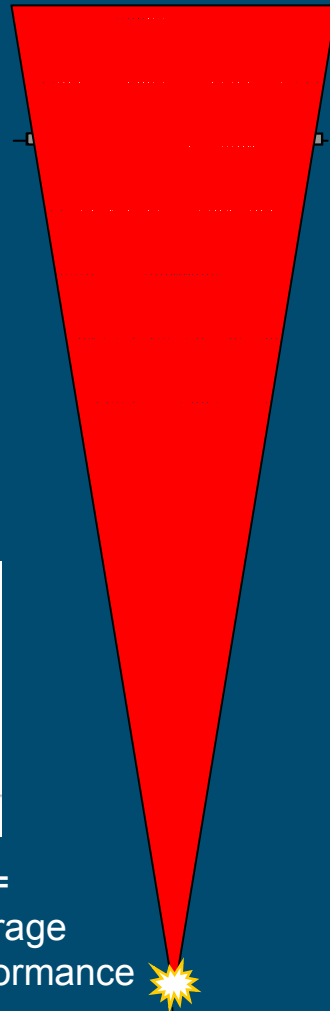


# Effects of Burst Distance

Target



**Increased Burst Distance** =  
Greater Sub-projectile Coverage  
Decreased Penetration Performance



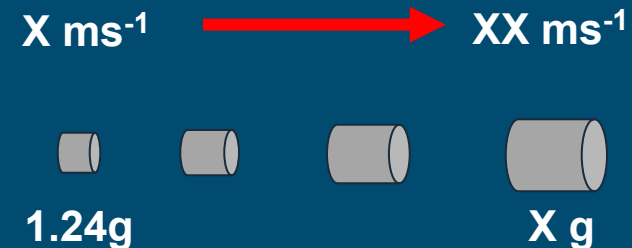
**Decreased Burst Distance** =  
Decreased Sub-projectile Coverage  
Increased Penetration Performance

# ABM Future Work

- Trial planned for May - Jun 05
  - Different Design of ABM by General Dynamics (High Explosive Air Burst)
  - HEI rounds will be fired for direct comparison against target plates
- Gas Gun firings and Modelling to determine optimum sub-projectile size and associated lethality against threat set
- Results feed directly into both UK and US Navy Procurement Programmes
  - T23 Upgrade
  - US LPD17 & EFV



**GENERAL DYNAMICS**  
Ordnance and Tactical Systems



# Potential Platforms for ABM



3 May, 2005  
© Crown Copyright Dstl 2005

UNCLASSIFIED



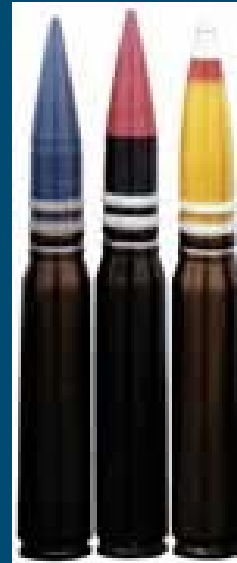
Dstl is part of the  
Ministry of Defence

# Effects of High Explosive Rounds



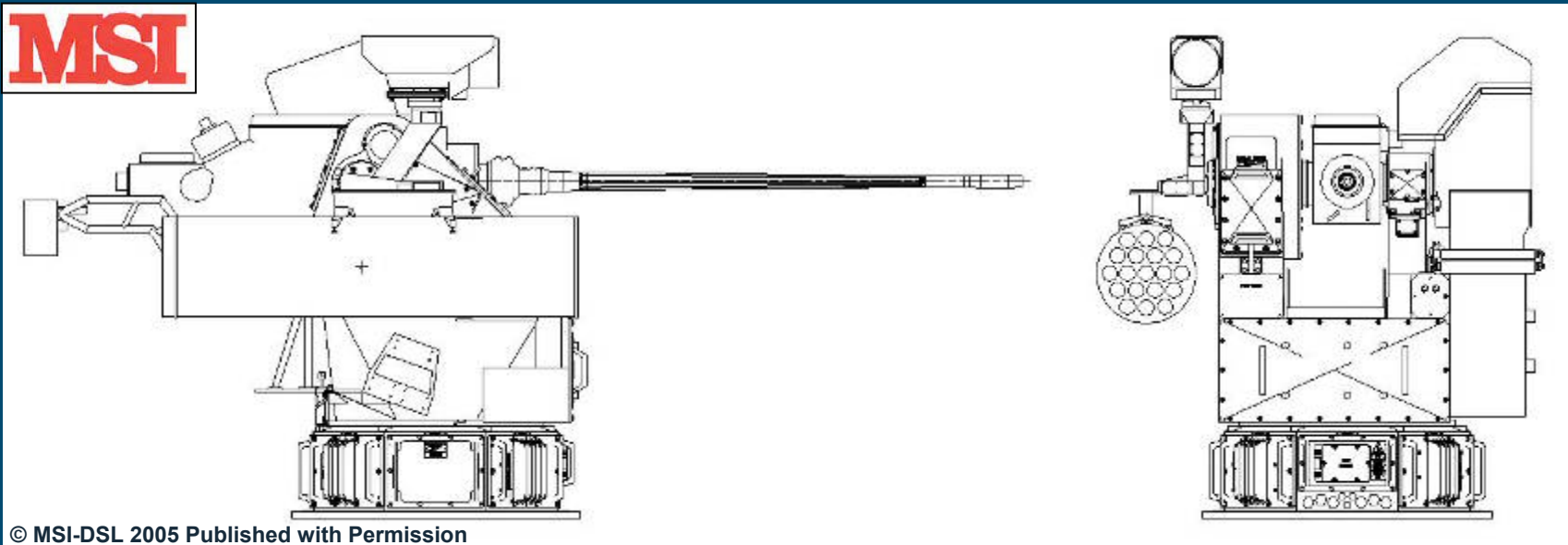
# Future Ammunition Work

- Investigate Lethality of a COTS range of Ammunition against precisely defined representative targets
- Larger calibres considered
- Using Typical threat materials and suitable position (e.g. angles)
- Determine required gun/ammunition lethality against the threat set

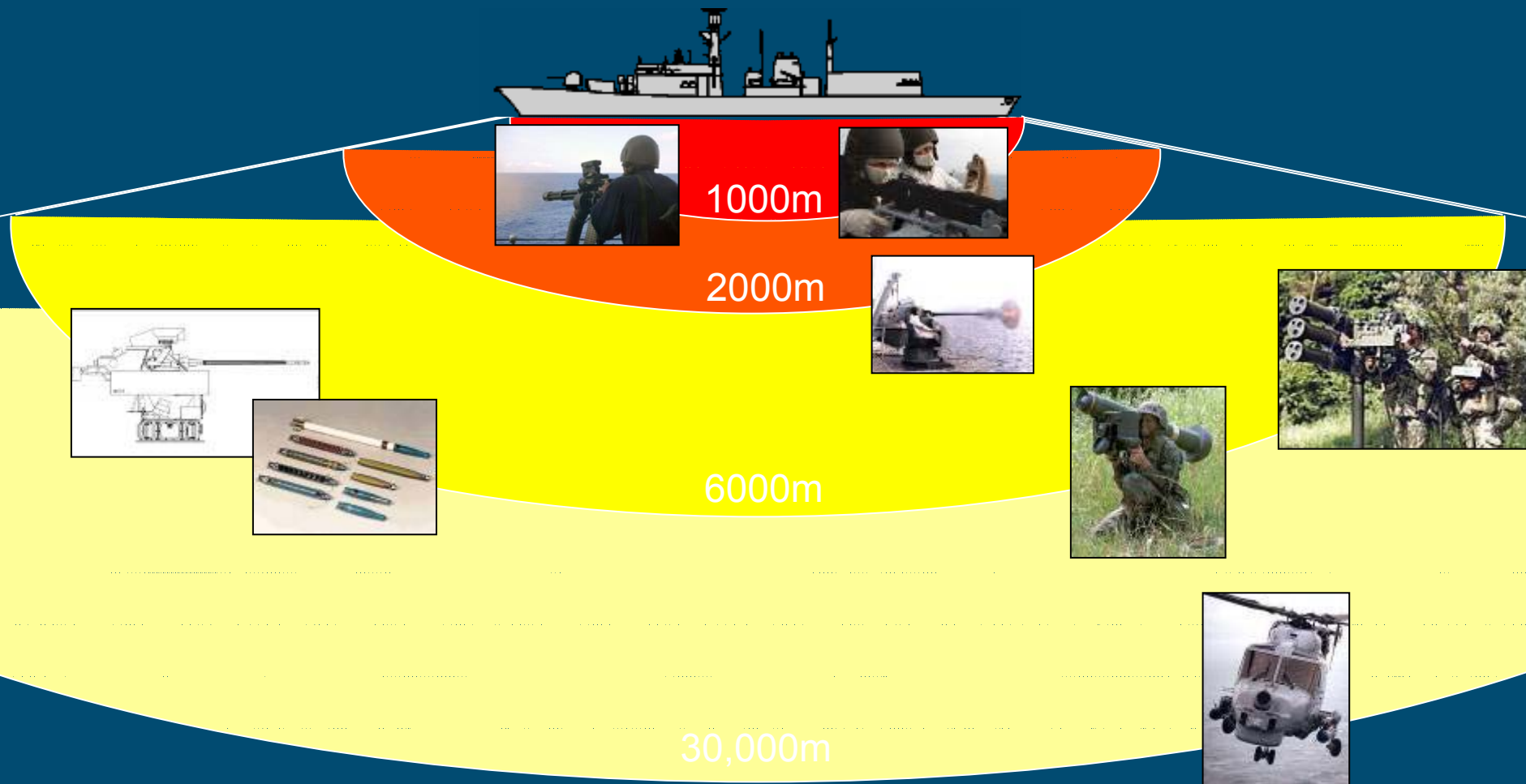


# Hybrid Gun Mount

- 70mm Low Cost Rocket
- 6km Range (Increased with Guided Variant)
- Studies Conclude Launcher fit is feasible
  - Issues with Local Control Position



# A Layered Defence



# Implications of Swarm Attack

- Investigate Impact of dealing with a FIAC Swarm Attack from a SCGS
- Human Factors
  - Examine Human Computer Interface for Operator control
  - Prevent the operator from being overwhelmed?
- Can Technology assist?
  - Target Prioritisation?
  - BDA?

